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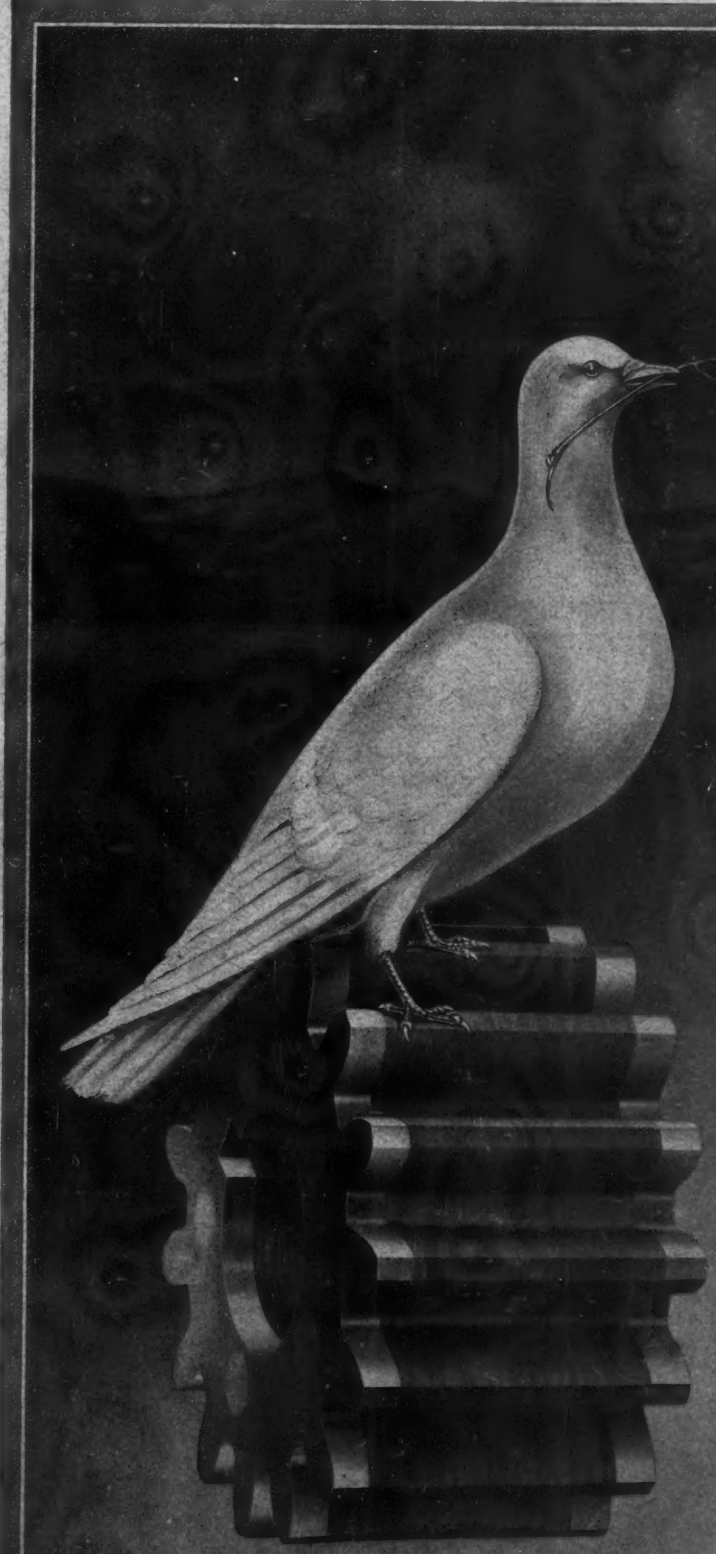

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OCTOBER MACHINERY 1915

Oxy-Acetylene Welding and Cutting Equipment*

by S. W. Miller ††

Ten years ago the oxy-acetylene method of welding and cutting metals was hardly more than a laboratory process, but in the course of these few years it has become one of the most important methods in the metal-working industries. It has made possible the making of repairs in broken machine parts that previously had to be replaced by an entirely new casting or forging. Not only has the process proved of the utmost importance in repair work, but its application has also proved of the greatest value in the manufacture of many articles. Much has been published relating to this process, but the articles have generally been descriptive of odd jobs. It is believed that the series of articles in Machinery beginning in this number will constitute one of the most complete records of the principles and practice of the art of oxy-acetylene welding that has so far appeared in any publication. The wide experience of the author in the practical application of the process, and the success he has attained in his business, vouches for the reliability of the extensive treatise here published.

WELDING is understood by the average person to mean the uniting of two pieces of steel or iron by heating to the temperature at which they become softened, without melting them, placing them together, and hammering, or in some way bringing them into intimate contact. As is well known, this cannot be done in the case of the common metals other than wrought iron or steel. It will however be readily seen, even by those unfamiliar with oxy-acetylene welding, that if two pieces of metal can be melted together the union will be sound and the joint invisible, even in the case of a casting. The fact that this could be done in the case of cast metals such as cast iron, cast steel, brass, etc., has been known for years, and the use of this method—termed "burning in" in foundries—is of frequent application. However, there is no assurance that a sound structure will be produced, because there is no possibility of observing what is going on at the junction of the old and new metals. The field of application is somewhat limited, and the results frequently unsatisfactory, owing to the conditions under which the work is done.

If, however, some process were devised by which these difficulties could be overcome, that is, by which the action of the melted metal could be observed and the expansion and contraction could be taken care of, and by which it could be insured that sound unions would be made under all conditions, it is evident that a very useful addition to the mechanical arts would be produced, and one which would be of wide application. Such is the oxy-acetylene process, or, as it is frequently called, "autogenous welding," the word "autogenous" meaning "self-produced." The use of the term "autogenous" is rather unfortunate. As stated, it means self-produced, which is certainly not true in the case of a weld made by the oxy-acetylene process. The word "autogenous" is used in biology and physical geography in its correct sense. The idea that should be conveyed by any term describing this kind of a weld is that it is made with the same kind of material as that of which the piece is composed. The word "autogenous" does not convey this meaning.

Another idea that should be conveyed is that the process involves the melting of the metal during the making of the weld. It might be possible for one skilled in the dead languages to devise some term that would cover these points, but it would undoubtedly be a cumbersome word or combination of words, and therefore as unsatisfactory as the word "autogenous". Probably there is no word which conveys all of the ideas involved, but "homogeneous" would better explain the uniformity of the character of the weld than "autogenous". This is, however, a long word and not really descriptive of the process.

As stated, one of the essential features of the process is the melting of the metal, and as it is not true in all cases that the process uses the same kind of metal for joining as is in the original piece, it would seem that the term "fusion weld", which is short, descriptive and distinctive, should be entirely satisfactory. The author will therefore use it in these articles, employing also at times the term "homogeneous" to describe, when necessary, the uniform character of the weld and piece. In certain cases other gases than oxygen and acetylene are used, but it is not necessary to consider them here, as by far the most important work in fusion welding is done by the use of oxygen and acetylene.

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* For previous articles referring to oxy-acetylene welding and kindred subjects see MACHINERY, August, 1915, "Fluxes for Oxy-Acetylene Welding"; June, 1915, "Fluxes for Oxy-Acetylene Welding"; October, 1912, "Pre-heating Metals to be Welded by Oxy-Acetylene Process"; January, 1912, "The Manufacture of Tubing by Autogenous Welding", and other articles there referred to.

† Address: Rochester Welding Works, 406 Orchard St., Rochester, N. Y.

‡ S. W. Miller was born in New York City and graduated from Stevens Institute with the degree of mechanical engineer. He served a special apprenticeship in the shops of the Pennsylvania Lines West of Pittsburg, and among other positions has held that of master mechanic of the Pennsylvania Lines, and superintendent of the American Locomotive Co. He is now the proprietor of the Rochester Welding Works, Rochester, N. Y., which he has conducted for five years past. His specialty is oxy-acetylene welding and research work connected with this branch of mechanical development.

Equipment for Welding

The welding equipment necessary will depend on the kind and amount of work to be done. It will include the necessary torches and hose, oxygen and acetylene generators or containers, pressure gages and reducing valves, dark glasses, etc. Only the best apparatus should be purchased, and as in many other cases, it is advisable to know that the manufacturer is sound financially and is going to continue in the business. The patent situation with regard to welding equipment, and even in regard to certain processes, is somewhat confused at the present time, and it is well to be sure that after it is cleared up repair parts can be obtained. The manufacturers of the best apparatus have more experience and are able to give assistance and information to the beginner which is not obtainable elsewhere. Poor apparatus is expensive to operate and therefore costly, even when the purchase price may appear low.

The Welding Torch

The first practical welding torch was devised by Fouché and Picard in France in 1901, and the first industrial application was made by them in 1903, after many experiments to avoid the danger from explosion. It was also found necessary to take care of "back-firing". If a tube of comparatively large diameter is filled with a gas and ignited at one end, the flame will travel to the other end at a certain speed, depending chiefly on the nature of the gas, but also on some other considerations, such as the size of the pipe. The flame from ordinary city gas or natural gas will not travel back through pipes of the size ordinarily used in carrying it. It has been found, however, that it is necessary to have a very small pipe to prevent this action in the case of acetylene, and also that the speed of travel of the flame is very high in the case of this gas. The dangers resulting from not taking proper precautions to prevent such flame-travel are well illustrated in the terrific mine explosions which have occurred and which have been duplicated in experiments on full-sized tunnels in which the speed of travel of the flame of burning mine gases has been accurately measured.

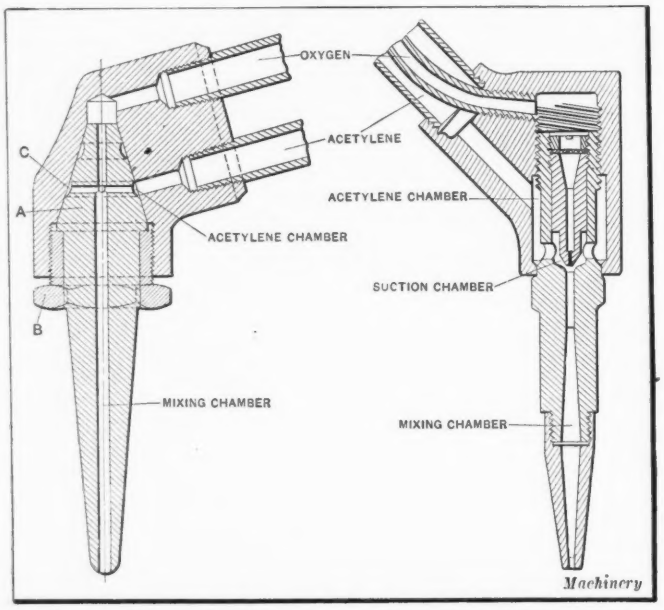

Fig. 1. Tip of So-called "Positive-pressure" Torch

Fig. 2, Tip of Low-pressure Torch

It is evident, however, that if the gas issues from the end of the pipe with a velocity greater than that with which the flame travels backward in the pipe, it will burn without any danger. In the early torches with comparatively large acetylene openings, it was necessary to provide a chamber in the torch filled with asbestos and provided with wire gauze partitions to prevent this back-firing; but it was later found possible to do away with this precaution if the acetylene holes in the head of the torch were made sufficiently small.

There are a large number of torches on the market, some of which are good and some of which are bad. One of the most essential features of a torch is the use of as little oxygen as possible in proportion to the acetylene used; early torches were very defective in this respect. The result of this was unsatisfactory welds, particularly in steel or any metal which is easily oxidized, such as aluminum. Modern torches give much better results, and it is believed that still further progress will be made in the future. The actual amount of oxygen used should be the same as that of acetylene, and this is quite closely approached at the present time in some torches.

It has been stated that the intensity of the flame from an oxy-acetylene torch is the highest that can be produced by the burning of gases. It is impossible to measure the temperature directly, but from theoretical considerations it has been determined that it is about 6300 degrees F. When it is considered that the melting point of cast iron is about 2100 degrees F., that of soft steel about 2600 degrees F., and of wrought iron about 2700 degrees F., it will be seen that there is no difficulty whatever in melting any of the metals.

Good welding can be done with any good torch; as stated, the best is the one which uses the least oxygen in proportion to acetylene, because it is less expensive in operation and tends to give a more neutral flame. The number and sizes of the torches depend on the character of work to be done, but there should always be a full set of tips provided. If this is not done experience proves that a time will come unexpectedly when a tip not on hand will be needed. Hose should be of the best quality. It is subject to quite heavy strains, and as the lighter the torch is, the easier it is to handle, the best quality is necessary to avoid excessive wear.

The oxy-acetylene welding torches which are in use at the present time may be divided into two general types, according to the pressure under which the acetylene is supplied. These are known as the low-pressure torch and the medium or "positive" pressure torch. The term medium-pressure is employed to distinguish torches of this type from the high-pressure torches which were used in France at the time that the oxy-acetylene welding and cutting industry was in the early stages of its development; this name also distinguishes the medium-pressure torch from the so-called low-pressure torch in which the acetylene is delivered at slightly above atmospheric pressure, while the oxygen is under a higher pressure than is the case with the medium-pressure type of torch. As the pressure under which the gas is delivered at the outlet from the tip or burner is necessarily that of the gas which is at the highest pressure, the low-pressure torch may deliver the mixed gas at a higher pressure than that under which the gases are delivered from the medium-pressure torch. The low-pressure torch works on the injector principle, the oxygen being under high pressure so that it flows rapidly through the duct in the head of the torch and draws in the acetylene. As the two gases flow on through the duct or mixing chamber in the head or burner tip, they are mixed together ready for combustion to take place as they emerge from the orifice at the end of the tip.

In the medium- or positive-pressure type of torch, both the oxygen and acetylene are under pressure, so that the flow of the acetylene is controlled without employing the injector principle. In this type of torch the oxygen and acetylene are carried to the head through two tubes which deliver the gas into a mixing chamber; and the mixed gas then flows through this mixing chamber or duct to the orifice at the tip of the burner. It will be noted that in both types of torches shown the oxygen and acetylene travel through a duct of considerable length, so that a complete mixture is obtained by the time the orifice at the tip is reached. Figs. 1 and 2 illustrate medium- and low-pressure torches.

Figs. 1 and 3 show the design of welding torch which has been adopted as a standard construction by the Davis-Bournonville Co., New York City. This torch is made in different sizes to meet the requirements of various classes of work. One of the basic principles of this type of torch—which was covered in the original French patent and also by patents in the United States—provides for using different sizes of interchangeable burner tips in a given size of torch, in order to adapt it for handling various kinds of work. The gases enter the tip at separate points, and the pressure of each gas is

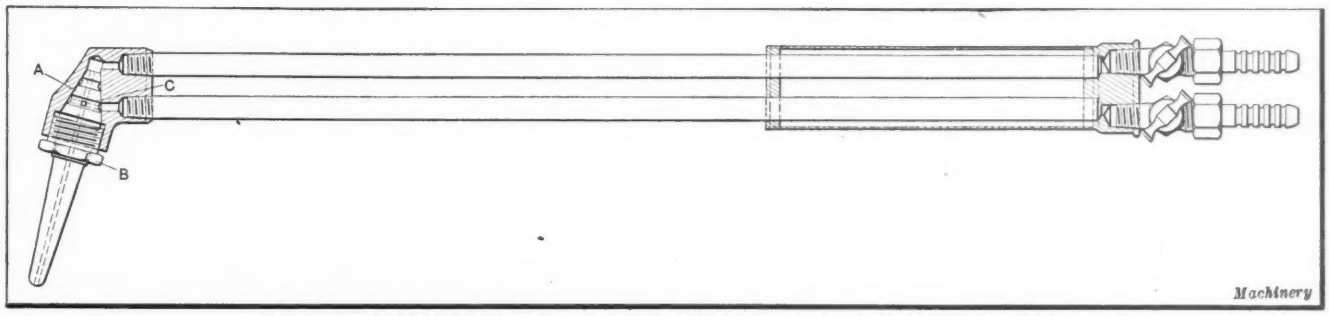

Fig. 3. Standard Type Positive-pressure Welding Torch as made by the Davis-Bournonville Co.

regulated to obtain exactly the required mixture. Each tip provides a size of flame suitable for various classes of work. In this connection it is interesting to note that a patented construction has been employed for fitting the burner tip into the head of the torch. Instead of using a threaded joint, it will be noted that the tip is tapered at *A* to fit a tapered socket in the head of the torch. This does away with trouble from damaged threads which resulted from the earlier construction in which the tip was screwed into the head; and leakage caused by expansion or contraction of the different parts of the torch due to variations in the temperature has been done away with. It will, of course, be evident that the tip is held in place in the head of the torch by the nut *B*, and that the oxygen enters the tip through the axial duct, while the acetylene enters the groove *C* which leads the gas to the four ports or transverse ducts in the tip.

Each of the two sizes in which this torch is made is provided with five different sizes of tips. The five smaller sizes provide for welding metal from 1/32 up to ¼ inch in thickness, while the five larger sizes are employed for heavy welding operations on metal from ¼ inch in thickness and up. When using each size of tip, a definite specified pressure of the oxygen and acetylene is secured through the use of pressure regulators. The pressure of the oxygen and the size of the axial duct in the tip bear such a relation to the pressure of the acetylene and the size of the ports or transverse ducts, that the ratio between the consumption of oxygen and acetylene is 1.14 to 1, which gives a neutral flame.

Fig. 2 shows a cross-section of the welding head of the Oxweld low-pressure or injector type of torch, as made by the Oxweld Acetylene Co., Chicago. The notation in the illustration shows the construction clearly. Fig. 4 shows a type of torch which differs in its arrangement to a considerable extent from the other two types shown. This is made by the Prest-O-Lite Co., Indianapolis, Ind. This torch is used for compressed or medium-pressure acetylene only, and therefore no injector device is necessary. The gases mix near the handle, and flow together along the full length of the stem. The handle of the torch is fitted with "anti-fire-back" chambers for both gases, filled with material through which it is impossible for the flame to pass.

Cutting Torches

In cutting iron and steel with the oxy-acetylene torch, the cut is made by the burning away of the metal along the line on which the cut is to be made. In order to understand the operation of the cutting torch, the reader must first grasp the idea that the burning of any matter—regardless of whether it is coal, oil, wood, or metal—is due to the chemical combination of the oxygen with the material which is being burned. In the case of iron and steel, this burning action can only take place at very high temperatures and for this reason the metal is heated by means of the oxy-acetylene flame, which raises its temperature to a point where the metal will combine with the oxygen; but ordinary air consists of one part of oxygen to four parts of nitrogen, and as a result the cutting action would be quite slow if additional oxygen were not supplied. In the early forms of cutting torches, this was done by attaching a separate tip at the side of the welding torch, which was connected to a third tube that carried an auxiliary supply of oxygen and discharged it against the heated metal. The flow of oxygen through this auxiliary tip was controlled by means of a valve which was held open by depressing a thumb-lever.

To avoid the use of this construction, and to provide a cutting torch on which only two hose connections are required, the Davis-Bournonville Co. is now manufacturing a torch of the form shown in Fig. 5. In this torch there are two rubber tubes which connect the torch with the supply of oxygen and acetylene. The torch itself is provided with three metal tubes *A*, *B* and *C*, and the tip is drilled with three longitudinal ducts *D*, *E* and *F*. Each of the ducts *D* and *E* delivers a mixed supply of oxygen and acetylene which burns at the tip of the burner, serving to heat the metal to the oxidizing temperature. So far as the method of effecting the mixture of the oxygen and acetylene is concerned, each of the ducts *D* and *E* is analogous to the ducts of the welding tip which has already been described. The central duct *F* delivers a supply of pure oxygen to the metal when the thumb-lever *G* is thrown over to open the valve in tube *A* to the oxygen supply. This pure oxygen strikes the metal which has been heated to a high temperature by the oxy-acetylene flame and causes a rapid oxidation or burning of the metal to take place. In this way the metal is burned away along the line of the cut, but with a narrow saw-like kerf which, when the cutting is skillfully done, does not give the metal the appearance of having been burned or melted. The torch is made with three sizes of interchangeable tips for cutting different thicknesses of metal. The smallest tip cuts metal from ¼ to ¾ inch in thickness, the medium tip from 1 to 3 inches in thickness, and the largest size from 3 inches in thickness up. As in the case of the welding tips, each size of cutting tip uses the oxygen and acetylene under specified pressure.

Fig. 6 shows a group of the different styles of welding and cutting torches manufactured by the Davis-Bournonville Co. A large size of welding torch is shown at *A*, this being a standard torch for performing medium and heavy welding operations in making boiler repairs, and for general shop

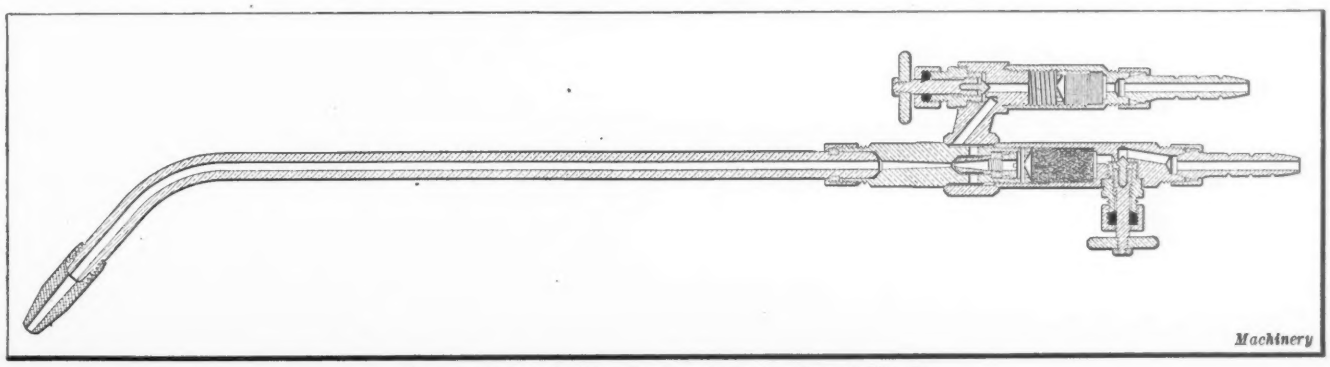

Fig. 4. Type of Welding Torch made by the Prest-O-Lite Co.

work. The torch is fitted with a set of the five large sized welding tips, and is adapted for welding metal from 5/16 inch in thickness up. It is 20 inches long and weighs 2 pounds. A special torch of this size is made in a 3-foot length for very heavy work where it is desirable to enable the operator to get as far away from the work as possible, owing to discomfort experienced from the intense temperature of the metal. The standard two-hose cutting torch is shown at *B*. This torch is 20 inches long and weighs 40 ounces. What is known as a "manufacturer's" torch is shown at *C*. This torch meets the requirements for light and medium sheet metal welding; it is especially adapted for manufacturing operations on boilers, steel barrels, iron and steel tanks, cylinders, etc. A small size of the standard welding torch is shown at *D*, this torch being convenient for use on light and medium sheet metal welding and on light repair work. Its length is 14 inches and weight 18 ounces. This torch is provided with a set of the five small sized tips, and is adapted for welding metal from 1/32 to 5/16 inch in thickness. A torch for circular hand cutting is shown at *E*. This torch is of the same general type as the standard cutting torch, but is fitted with a compass attachment to adapt it for cutting circular holes. Torches for use on cutting and welding machines are shown at *F* and *G*, and a torch with a water-cooled head and tips at *H*. This is for use on heavy welding where there is a tendency for the head and tip of the torch to become overheated from the intense heat radiated by the metal that is being operated upon. This is especially true in cases where the head of the torch is surrounded by the heated metal, and to overcome this difficulty a supply

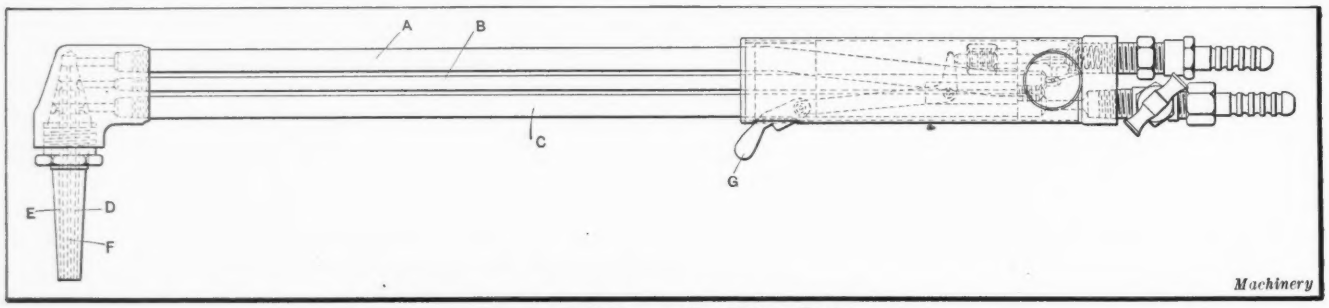

Fig. 5. Davis-Bournonville Cutting Torch

of cooling water is circulated through the head and tip by means of two extra hose connections provided for the purpose. At *I* is shown an oxy-hydrogen cutting torch in which hydrogen gas is burned in place of acetylene.

In Fig. 7 is shown the Oxweld cutting torch, which differs from the welding torch made by the same concern mainly in that an additional oxygen duct is provided.

Regulating Valves

Regulating valves should be kept in good condition. Unless this is done, so that the reduced pressure remains constant under all conditions, the action of the torch will be irregular and unsatisfactory. In the course of time the diaphragms become buckled, and have to be renewed. This and dirt in the small passages are the only difficulties in a well designed valve. Gages and regulating valves should be suitable for the work, and of substantial design. The gage capacity should be about one and one-half times the maximum pressure used. The gages for welding torch pressures should be graduated in single pounds, and need not have over 50 pounds capacity. For cutting torches the gages should be graduated to about 250 pounds. Good gages give practically no trouble.

Fig. 8 shows a section of the Oxweld Acetylene Co.'s oxygen welding regulator which reduces the oxygen tank pressure, about 1800 pounds, to that necessary for welding, as the latter pressure does not exceed from 10 to 30 pounds. Its action is as follows: The oxygen enters from the tank through passage *E* to valve *F*, the seat for which is held away from the valve by the spring *K* acting through the diaphragm *C*, which can be adjusted by turning handle *H*, to obtain any desired pressure. The oxygen then passes into chamber *D*, and when there is sufficient pressure, the diaphragm is forced to the left, allowing the small spring *M* to pull the valve seat against the valve and shut off the supply of oxygen. As soon as the pressure falls, the action is reversed, and the supply of oxygen is renewed. The oxygen passes from the chamber *D*, through a connection not shown, to the hose. The regulator for cutting is similar in design to that for welding, but as the cutting pressures may run up to 100 pounds, it is made heavier, and provides for a larger flow of gas. The differences in conditions make it necessary to use different regulators for welding and cutting, and good results will not be obtained unless the proper regulator is used.

Oxygen

Oxygen is a gas which constitutes about 20 per cent of the air in the atmosphere, the other 80 per cent being nitrogen, a gas which does not support combustion. Oxygen, however, is the active agent in maintaining life and combustion; its properties have been known since the end of the eighteenth century. Oxygen can be produced in several ways at such a price as to make it commercially useful. At the present time the largest proportion of it is made by the liquid air process invented by Dr. Linde in 1897. Almost every one remembers the demonstrations a few years ago of liquid air, and of the many curious and interesting things that were done by its use. Most of these things, however, were mere laboratory experiments, and its most important application, that of producing oxygen for commercial use, was not thought of at that time. The possibility of producing oxygen in this way has been one of the chief factors in promoting the use of oxy-acetylene welding, as it is has reduced the cost of the oxygen. The process simply consists in liquefying air and allowing it to again vaporize. The boiling points of oxygen and nitrogen are considerably different; hence. the gas desired may be collected and the other allowed to evaporate.

The oxygen, after purification, is compressed into cylinders or tanks, and can then be shipped wherever it is desired for use. The principal impurity in oxygen thus made is nitrogen, a percentage of which is likely to be present, and, which even when small, has an adverse effect on a weld, and is particularly objectionable when using a cutting torch.

The next most important process for producing oxygen is the electrolytic. The decomposition of water by electric current into its two elements, oxygen and nitrogen, has been practiced for many years; but it was not until the cost of electric current was reduced to a low point that it was possible to use this process commercially. It was also found by experiment and test that the production of an efficient and safe electrolytic cell was not an easy matter. It is, however, at the present time a thoroughly practical process, and one which is gaining ground daily. It is exceedingly flexible, and while the cost of cells is prohibitive for a small plant, yet, where considerable oxygen is used with regularity and the expense can be afforded, it is much used, as it produces the purest commercial oxygen. The only impurity in it of any importance is a small percentage of hydrogen, which does not injure the weld, nor is it of disadvantage in cutting, as it burns, producing heat.

There are a number of other processes for producing oxygen, the only important one being by heating chlorate of potash in a retort, passing the gas through a washing apparatus and collecting it in a gasometer. It can then be compressed to the required pressure and used as needed. Oxygen should never be generated from chlorate of potash under a pressure of more than a few ounces, on account of the danger of explosion. Oxygen, particularly when moist, as after passing

through a washer, attacks the piping, etc., resulting in a weakening of the pipes, which cannot be generally detected in time to prevent serious results. Oxygen is also liable to cause an explosion when it is heated and comes into contact with any carbonaceous material, such as splinters of wood, in the retort. Serious accidents have occurred from this cause. The method, however, is perfectly safe if care is taken and apparatus is procured from reliable manufacturers. The generation of oxygen from chlorate of potash under pressure is considered much more hazardous.

The gas produced by the chlorate-of-potash process is quite expensive, and contains a certain amount of chlorine which is detrimental to the strength of the welds and, therefore, unsatisfactory. This chlorine, however, can be removed entirely if proper apparatus is used, and under certain circumstances, as where the cost of shipping tanks back and forth is very high, the use of chlorate of potash for generating oxygen may be advisable. At the present time, the European war has greatly increased the cost of chlorate of potash, and this should be considered in making estimates.

As commercially used in the oxy-acetylene welding industry, oxygen may be made or bought. The latter is the cheaper method if the location is near a large plant making oxygen as a commercial product, as it saves the installing of a somewhat expensive apparatus. If it is necessary to make oxygen, either on account of cost or irregularity in delivery, the best process on a small scale is the heating of chlorate of potash in closed retorts, the resulting gas being passed through washers and collected in a gasometer, as described, from which it is pumped into tanks by a small compressor, generally belt driven. The usual maximum pressure in the tanks is about 300 pounds, and they generally have a capacity of 100 cubic feet of oxygen measured at atmospheric pressure. These tanks are convenient for shop use, but for outside work they are somewhat heavy and bulky, and can be replaced with advantage by smaller tanks of the same capacity, but having pressure of about 1800 pounds per square inch. These tanks are not sold, but are furnished, filled with oxygen by the oxygen companies on reasonable terms, and when empty may be returned for refilling. Oxygen can be obtained in this way much more cheaply and conveniently under ordinary conditions than by making it. It should be noted that all tanks shipped must comply in all respects with the requirements of the Federal Bureau of Explosives.

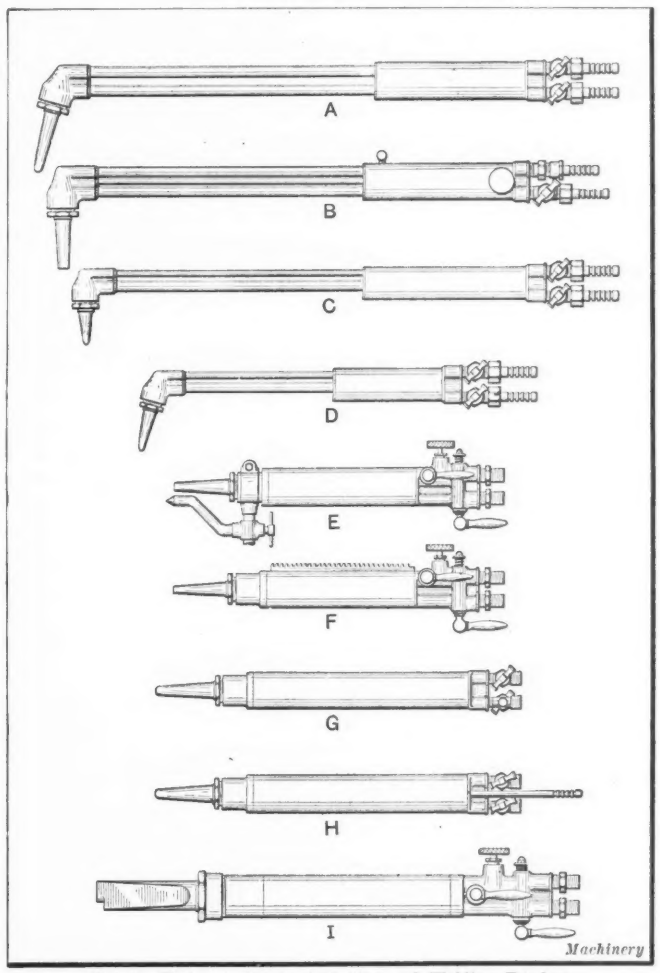

Fig. 6. Different Types of Cutting and Welding Torches

Potassium-Chlorate Method of Oxygen Generation

A diagrammatic view of the apparatus used for making oxygen by the potassium-chlorate method is shown in Fig. 9. The potassium chlorate is sealed in a retort *A* and heated by gas burners *B*. The heating causes the potassium chlorate to give off oxygen, but this reaction would proceed too rapidly if the charge placed in the retort consisted of pure potassium chlorate. It has been found, however, that by mixing thirteen pounds of manganese dioxide with 100 pounds of potassium chlorate the chemical reaction will proceed more slowly. The manganese dioxide plays no part in the chemical reaction, but is merely used as a retarding agent. Ten pounds of the mixture is put in the retort at a time. The gas from the retort is delivered through a series of three washers *C*, which serve to remove impurities, after which it passes on and is collected in the gasometer *D*. From the gasometer the oxygen is piped to the air compressor *E*, which compresses it into cylinders at the required pressure ready for use. The purity of the oxygen obtained by this method is slightly over 97 per cent.

Manufacture of Oxygen by the Liquid Air Process

In the manufacture of oxygen by the liquid air process, the oxygen is obtained by making a separation of the oxygen and nitrogen, which are the chief constituents of air. This is done by first bringing the air to the liquid condition by the combined action of high pressure and low temperature, and then separating the oxygen from the nitrogen by taking advantage of the difference in the boiling points of these two constituents of the air when in the liquid condition. This method allows oxygen to be obtained at a relatively low cost, but the plant required is only suitable for working on a large scale. Consequently, the method is suitable for the use of manufacturers of oxygen rather than for the users of welding and cutting torches who desire to make only enough oxygen for their own use. It is for this reason that many users of welding and cutting torches have found it more advantageous to buy their oxygen in cylinders ready for use than to make their own supply in a potassium chlorate or an electrolytic plant. To meet the demand from this class of consumers, the Linde Air Products Co. has established generating plants in thirty-seven of the most important industrial centers throughout the United States. These plants supply oxygen to the consumer, which is contained in pressure cylinders ready for use; and as a result of these numerous plants, many consumers get the advantage of buying their oxygen without having to pay freight on the filled cylinders or on the empty ones which must be returned to the generating plants. In many cities where there is not enough manufacturing to warrant the maintenance of generating plants, warehouses have been established in which a supply of filled oxygen cylinders is carried so that orders can be promptly filled; but in these cases the price is necessarily higher, as freight charges must be included.

It has already been stated that the method by which oxygen is obtained from the mixture of nitrogen and oxygen in the air, consists of first bringing the air to the liquid condition by the combined application of high pressure and low temperature, and then separating the oxygen and nitrogen by allowing the nitrogen to boil off from the mixed liquid. Fig. 10 shows a diagrammatic view of the plant employed for this purpose. This diagram gives a comprehensive idea of the principle involved and the general character of the equipment which is used. The diagram is presented simply as an adjunct to the following description, and many details have been omitted. It is well known that atmospheric air contains appreciable quantities of carbon dioxide gas, and the first step in the manufacture of oxygen by the liquid air method is to remove the carbon dioxide. This is done by drawing the air through a pit containing lime, which absorbs

the carbon dioxide by a chemical reaction resulting in the formation bf a compound known as calcium carbide. After leaving the lime pit, the air goes to a five-stage compressor in which the pressure is raised to 3000 pounds per square inch, and means are provided for cooling the air between each stage of compression so that it leaves the compressor at about room temperature. After leaving the compressor the air is delivered through pipe *A* to the "fore-cooler", in which the first reduction of temperature is effected. This fore-cooler is equipped with three sets of coils. The first coil contains carbon dioxide supplied from an external refrigerating system, and the other two coils contain the oxygen and nitrogen gas which have already been separated from the liquid air and are at very low temperatures.

As a result of its passage through the fore-cooler, the temperature of the air has been reduced to about zero degrees C. After passing through the fore-cooler, the air enters pipe *B* which carries it to a third unit of the plant, known as an "interchanger." This pipe *B* leads to a coil *C* which is submerged in the liquid air in the interchanger, and the purpose of passing the air through this coil will be subsequently explained. After leaving the coil *C*, the air, which it will be remembered is at a pressure of 3000 pounds per square inch, is allowed to pass through an expansion valve *D*, where the pressure is suddenly released. This results in a rapid expansion of the air, that, in turn, causes a further reduction of temperature, with the result that the air is brought to the liquid condition 'by this application of the Thomson-Joule principle. The liquid air passes through the vertical pipe to the top of the interchanger where it is discharged through the atomizer *E*, which is located at the top of a tower filled with perforated baffle plates *F*. The liquid air passes down over these baffle plates and finally reaches the container in which the coil *C* is submerged.

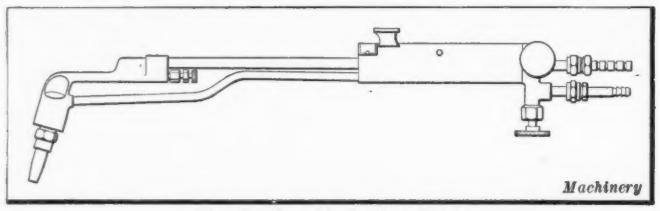

Fig. 7. Oxweld Cutting Torch

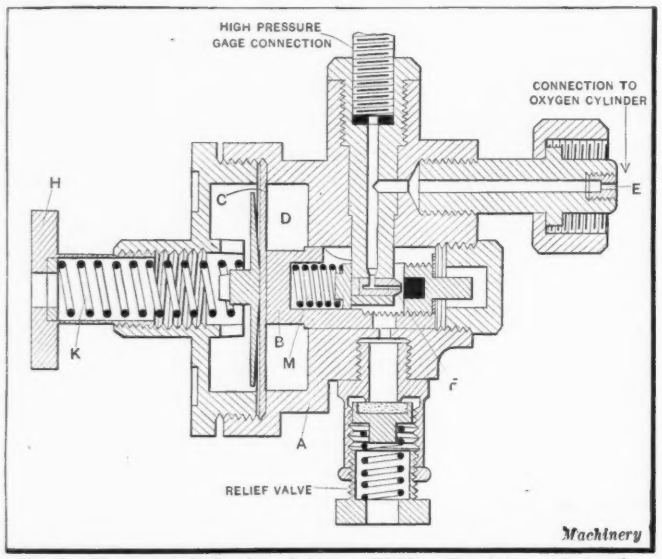

Fig. 8. Diagrammatic Section of Oxygen Welding Regulator made by the Oxweld Acetylene Co.

We are now in a position to go back to the reference which was made to the purpose of the coil *C*. It will be recalled that the air left the fore-cooler at a temperature of approximately zero degrees, and although this is a relatively low temperature, it is quite high when compared with the boiling points of liquid nitrogen and oxygen, which are 194 and 184 degrees C below zero, respectively. The result is that the passage of the air through coil *C* causes the liquid in the container to boil in the same way that a coil containing high-pressure steam would cause water to boil. But as the boiling point of nitrogen gas is 10 degrees higher than that of oxygen, the nitrogen must be removed from the liquid before the oxygen will start to boil. The result is that the nitrogen gas passes up through the baffle plates *F* in the tower, and in so doing heats the liquid air sufficiently to remove a large part of the nitrogen before the liquid actually reaches the container. The boiling of the nitrogen sets up a pressure in the interchanger which is sufficient to force the liquid oxygen up through the pipe *G* into the inner tube of the double coil *H* which surrounds the tower in which the baffle plates *F* are located; and the nitrogen which has been removed from the mixture passes down through the outer tube of the coil *H* which surrounds the tube carrying the oxygen. The result is that the oxygen gradually rises through the inner tube of the coil, and while doing so changes from the liquid to the gaseous condition. In order to keep the temperature of the interchanger down, the coils and other portions of the apparatus are carefully insulated by packing the space in the outer case with lamb's wool, which effectually prevents the absorption of heat from the outside.

After passing through the coil *H* in the interchanger, the pipes containing the oxygen and nitrogen—which are still at a very low temperature—are carried over to the fore-cooler where they enter two coils. It will be recalled that in the preceding description of the fore-cooler, mention was made of these coils through which the low-temperature oxygen and nitrogen were passed. The purpose is to utilize the low temperature of these gases to assist the carbon dioxide coil in reducing the temperature of the air as it passes through the fore-cooler on its way to the interchanger. After passing through the coil in the fore-cooler, the oxygen and nitrogen pass out through pipes and the oxygen is ready to be collected in compression cylinders. At the present time the only use for the pure nitrogen gas which is made by this method is in incandescent electric light bulbs. Nitrogen is very suitable for this purpose because it is chemically inert, and so does not have any effect upon the incandescent filament. Research work is also done with the view of developing a method of "fixing" the nitrogen, *i. e.*, of developing a method of chemically combining the nitrogen with some other element or elements so that it may be used as a fertilizer, and in various chemical industries. The Linde Air Products Co. is prepared to guarantee a purity of 98.5 per cent for its oxygen, and as a matter of fact, the purity is in the neighborhood of 99 per cent. The 1 per cent of impurity is nitrogen which is chemically inert, so that it has little detrimental effect upon the steel or other metal which is being welded.

The Electrolytic Method of Generating Oxygen

For those shops which use oxygen in sufficient quantities to warrant the installation of a plant for generating the gas by the electrolysis of water, there is probably no more satisfactory method. It is well known that water is composed of two parts of hydrogen chemically united to one part of oxygen, and that when an electric current is passed through water—with the necessary amount of sodium hydroxide, potassium hydroxide, or some other chemical dissolved in it to make the solution a conductor of electricity—the chemical bond between the hydrogen and oxygen will be broken down. The result is that hydrogen gas is given off at the cathode or negative pole and that oxygen is liberated at the anode or positive pole of the electrolytic cell.

In the manufacture of oxygen by this method, the electrolyzer in which the dissociation of the hydrogen and oxygen takes place is so arranged that the two gases are kept separate from each other and carried off through individual pipes. Fig. 11 shows the arrangement of the type of electrolytic cell made by the Davis-Bournonville Co. The reservoir in which the potassium hydroxide solution is contained is divided by a metal plate *A*; and an anode *B*, on which the oxygen is formed, is suspended in the solution on each side of the partition. The cell itself is made of metal, and the container and metal partition form the cathode or negative pole from which hydrogen is evolved. To provide for keeping the oxygen and hydrogen separate, an asbestos cur-

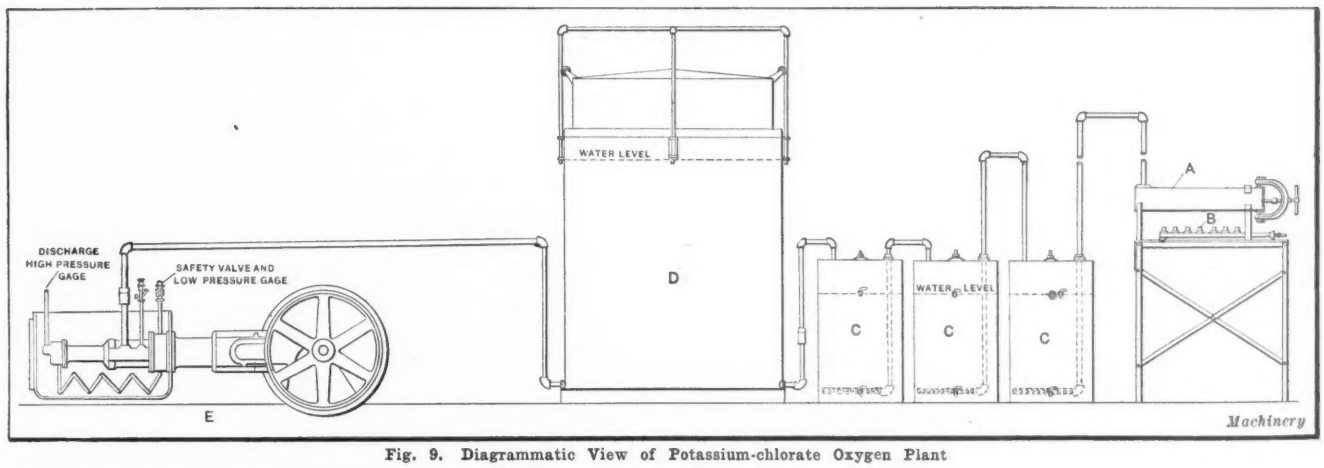

Fig. 9. Diagrammatic View of Potassium-chlorate Oxygen Plant

tain surrounds each of the anodes *B;* this curtain extends almost to the top of the cell and keeps the oxygen separate from the hydrogen. The oxygen gas is carried off through the two pipes *D* which are connected with the off-take pipe *E*, that carries the oxygen from all of the cells to the gas holder in which it is collected. Similarly, the hydrogen is carried off from the cell through pipe *F*, which is connected with pipe *G* that carries the hydrogen from all of the cells.

When the electric current is passed through the cell, the entire volume of water is placed in a state of charge, which results in the liberation of oxygen at the anode and hydrogen at the cathode. There is no tendency for these gases to be liberated at any point except at their respective terminals in the cell, and so the asbestos separator *C* will keep the two gases from mixing. It is important, however, for the pressure of the oxygen and hydrogen to be kept the same, in order to avoid the tendency for the gas at higher pressure to be forced through the asbestos curtain. This equalization of the pressure is provided for by having the two pipes *E* and *G* pass the gas which they carry through two water seals. These are arranged so that the pressure head of water is the same in each seal, and, as a result, the back pressure exerted on the oxygen and hydrogen leaving the cells is maintained exactly the same. Some factories make a practice of collecting the hydrogen gas which is generated, for use in oxy-hydric cutting torches; and, in certain cases, the hydrogen has been employed for filling the bulbs of incandescent electric lights. In many shops, however, it is not found worth while to attempt to utilize the hydrogen, and in such cases this gas is allowed to pass off into the atmosphere.

Fig. 12 shows the arrangement of a complete plant for the generation of oxygen and hydrogen by the electrolytic method, in which provision is made for collecting both the oxygen and hydrogen. In this illustration, the motor generator which supplies current to the electrolytic cells is shown at *A*. The cells are shown at *B;* the gas holders for the oxygen and hydrogen, at *C* and *D*, respectively; the compressors for compressing the oxygen and hydrogen, at *E* and *F;* and the pressure tanks to which the compressors deliver the oxygen and hydrogen, at *G* and *H*. It will also be noted that provision is made for connecting portable cylinders *I* and *J* direct to the compressors so that these cylinders may be filled with oxygen and hydrogen.

In presenting a description of the operation of the plant, it will simplify matters to refer only to the equipment used for the generation and compression of the oxygen. The equipment shown for handling the hydrogen gas works on exactly the same principle, so that one description will apply in both cases. Upon leaving the electrolytic cells *B*, the oxygen is passed along to the gas holder *C*, which is of the standard type in which an inverted bell is suspended over water by means of a counterweight. As the oxygen enters the gas holder the bell rises, and when it has reached a predetermined limit—or when the gas holder is filled to its capacity—an automatic switch is thrown which starts the electric motor that drives the oxygen compressor *E*. This results in pumping oxygen out of the gas holder and compressing it in the oxygen pressure tanks *G*. These tanks are usually arranged for a maximum pressure of 300 pounds per square inch, and when this has been obtained a pressure regulator of the Bourdon spring type, which is located on the switchboard *K*, throws a relay that, in turn, trips the compressor motor switch and stops the compressor.

While the compressor is in action it will be evident that oxygen is being withdrawn from the gas holder *C*, with the result that the bell descends; and when the bell has reached the lower limit of its travel—so that practically all of the oxygen has been pumped out of the holder—an independent electric switch will be thrown to stop the compressor motor. When the compressor is stopped in this way, the motor gen-

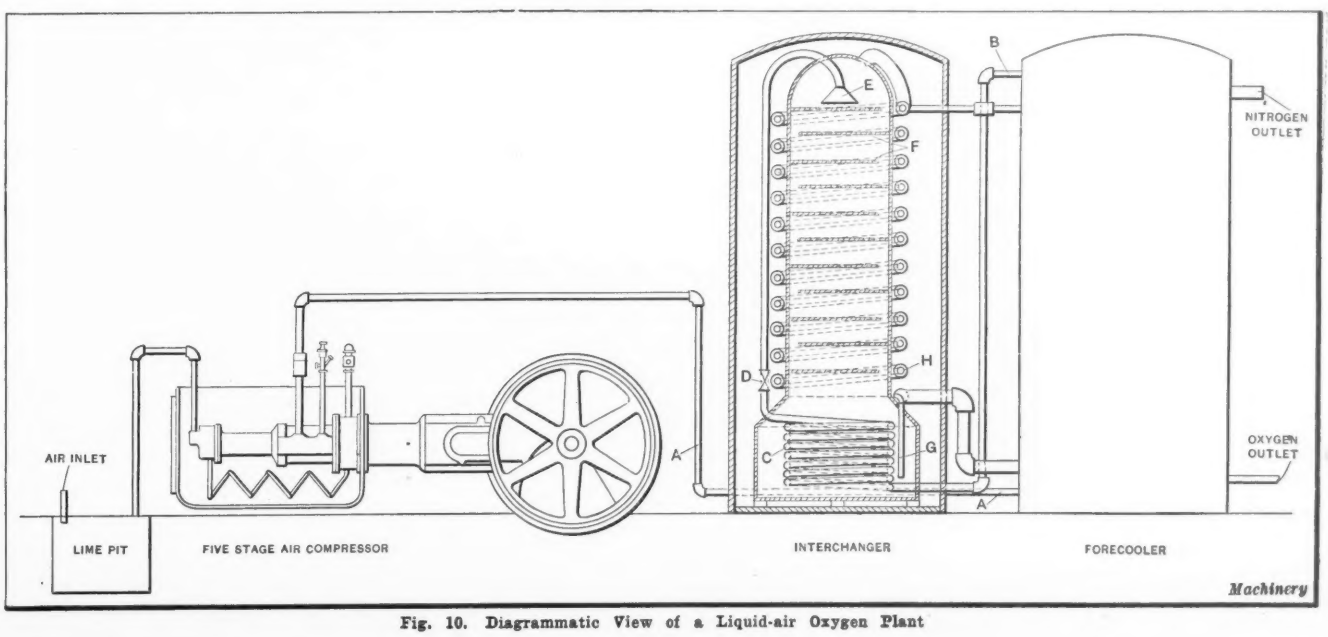

Fig. 10. Diagrammatic View of a Liquid-air Oxygen Plant

erator *A* continues to run so that the supply of oxygen from the electrolytic cells *B* is continued until the gas holder *C* is filled to its capacity. When this result is obtained the normal sequence of events would be for the switch which governs the compressor motor to be thrown over, in order to start the compressor. It may happen, however, that the pressure in the oxygen tanks *G* is at the maximum of 300 pounds per square inch; when such is the case means are provided to make it impossible for the switch to be thrown to start the compressor motor. Under such conditions, an automatic switch is thrown, which stops the motor generator and cuts off the generation of oxygen in the electrolytic cells. As soon as the oxygen in the pressure tanks has been partially consumed, thus lowering the pressure, the compressor motor automatically starts to deliver more oxygen to the pressure tanks, with the result that the gas holder starts to descend. This, in turn, closes the switch controlling the motor-generator set, which restarts the motor-generator and causes the electrolytic cells to begin to generate more oxygen. The 500-ampere cell requires 1¼ gallon of water to be added each twenty-four hours, and the 1000-ampere cell requires 2½ gallons of water per twenty-four hours; otherwise the only attention necessary is the maintenance of the different units of the plant in running order, and this takes very little time. The purity of the oxygen generated by this process is in excess of 99 per cent.

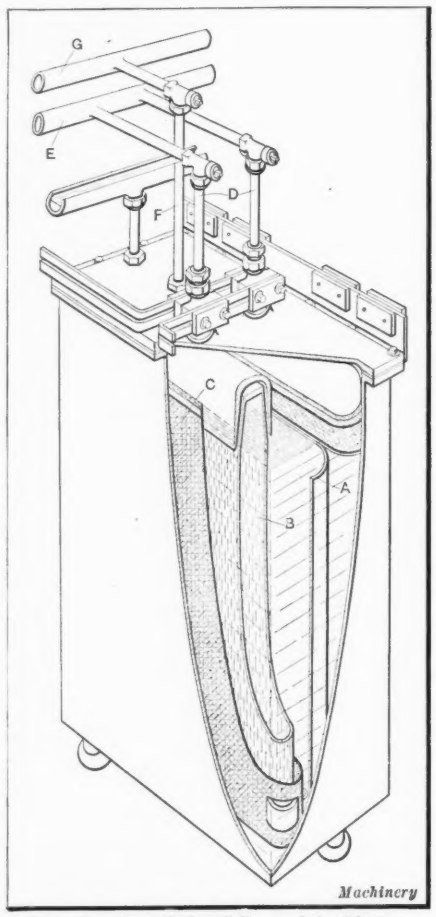

Fig. 11. One of the Cells used in Electrolytic Oxygen Manufacture

Acetylene

Acetylene has been known for a great number of years, having been discovered in 1836, but until 1892 its production was merely a laboratory experiment. In that year calcium carbide was accidentally manufactured in an electric furnace at the works of the Willson Aluminum Co., in North Carolina. It was considered of no value and was thrown into the river. It was then accidentally discovered that the gas arising from it when thrown into water, would ignite, and a further investigation proved that this was acetylene. Its commercial exploitation began shortly afterward in its use for isolated lighting plants, as in a suitable burner it produces an intensely white and very pleasing flame; and as the generation is comparatively easy and safe, it has attained a wide popularity.

Acetylene is composed entirely of carbon and hydrogen, both of which elements, when combined with oxygen, burn, producing heat. Acetylene has the property of having more heat units per cubic foot than any other gas; it contains in this volume 1630 heat units, or nearly five times as many heat units as hydrogen. Consequently, if it were completely burned, it would produce the maximum temperature possible in a gas flame. This was appreciated by a number of experimenters, but they found great danger from its explosive properties. For instance, if mixed with air and compressed to about 30 pounds gage pressure, it explodes. Even if not mixed with air it cannot be compressed above this pressure and subjected to heat, shock or other disturbances without being decomposed into its elements; and then a violent explosion results. This is one reason why acetylene generators must be properly designed and taken care of; also, to prevent overheating, a large excess of water should be used, as one pound of carbide will raise the temperature of one gallon of water 90 degrees F.

It has been found, however, that certain liquids have the peculiar property of absorbing many volumes of acetylene. The most satisfactory liquid for this purpose is acetone, and this is used in all compressed acetylene tanks at the present time. It is also found advantageous and safer to fill these cylinders completely full of asbestos or other porous material, so that there will be no chance of dead spaces which might otherwise become filled with air and make the cylinders more or less unsafe. In this porous material is contained the acetone, and in the acetone is dissolved the acetylene. It is perfectly safe to compress acetylene into such tanks, and they have been subjected to the most violent shocks, such as firing a rifle bullet through them, dropping large weights on them, and even putting them into hot fires, without explosion. Acetylene may also be produced in a generator suitable for the purpose by bringing in contact water and calcium carbide. This produces gas more cheaply than that furnished in tanks, and if the generator is of the proper design, it will be found entirely satisfactory for most welding.

Generating Acetylene Gas

When calcium carbide is brought into contact with water, acetylene is given off and slaked lime left as a residue. There are three kinds of generators, the essential differences being the methods of uniting the carbide and the water. These methods are:

1. Dropping the carbide into a large body of water.
2. Allowing the water to rise slowly against the carbide.
3. Dropping the water on the carbide.

The first is by far the safest method; it keeps the pressure uniform, gives cooler and purer gas, and is in every way to be preferred. In any case, the directions furnished by the makers of the generator should be strictly followed, or an explosion may result. The safety valve should be tested daily to be sure that it is working properly; the regulator should be kept in condition so that the working pressure will be kept within proper limits; leaks of all kinds should be carefully avoided; and the feeding mechanism should be stopped, and the cut-out valve in the supply pipe shut off every night or when the generator is out of service for any length of time. Keep flames or lights of any kind away. An excess of precaution is advisable in handling acetylene, and the matter of insurance should receive special attention, as improper location or installation may invalidate any insurance in force. If the generator is worked too hard it will become hot, and in this condition is dangerous. The maker can say how many torches of a given size should be connected and working at one time. If a generator becomes hot for any reason, stop the use and generation of gas until it is cooled down, no matter how long it takes.

A generator with carbide in it should never be moved around; it it liable to be upset, and the water, coming suddenly in contact with a large quantity of the carbide, will raise the pressure to the explosive point, which is about 30 pounds per square inch when acetylene has any air mixed with it. Fatal accidents have occurred from this. Freezing must be guarded against, but if thawing out is necessary, hot water applied externally is the only safe method to use. Where flash-back chambers are provided, keep them in proper condition, filling them with water every time carbide is put in. If any part of the generator is not understood by the user, consult the manufacturers; they will give full instructions and advice.

The end of the discharge pipe for the residue should be where it can be seen, so that if there is a loss of water due to a leaky valve, it can be noticed. If water is gradually lost, it may in time entirely drain out, and the generator will run hot. It will not give a sufficient or uniform supply

of gas and will be in a dangerous condition. Do not open the hand-hole, or any opening in the body of the generator, under such conditions, as it is liable to produce an explosion. Let the generator cool down until it reaches the room temperature. The proper method of handling depends on the type of generator, and if one is not sure what to do, he should consult the manufacturer. Explosions will never occur if the generator is watched and handled in the proper way.

There are two general types of acetylene generators used in the United States, which are called high- or medium- and low-pressure, respectively. The first uses acetylene under a pressure as high as 6 pounds per square inch at the torch, while the other uses a pressure of only about as many ounces. The torches for these two systems are entirely different in construction, and must be handled differently in operation. Care must be taken to follow the instructions of the manufacturers in regard to their operation in every case, or satisfactory results will not be obtained.

Impurities in Calcium Carbide

Calcium carbide, being made of coal or coke and lime by heating them together in an electric furnace, naturally contains some of the impurities in these substances. Neither coal nor coke is free from sulphur, nor is lime entirely free from phosphorus; therefore, acetylene made in a generator will contain more or less sulphuretted hydrogen and phosphoretted hydrogen, the amount depending on the purity of the original materials. These impurities, and the exceedingly fine dust that is sometimes carried over with the gas, give to the welding flame a somewhat yellow color which is not noticed when dissolved acetylene is used, the flame then having a slight violet tinge.

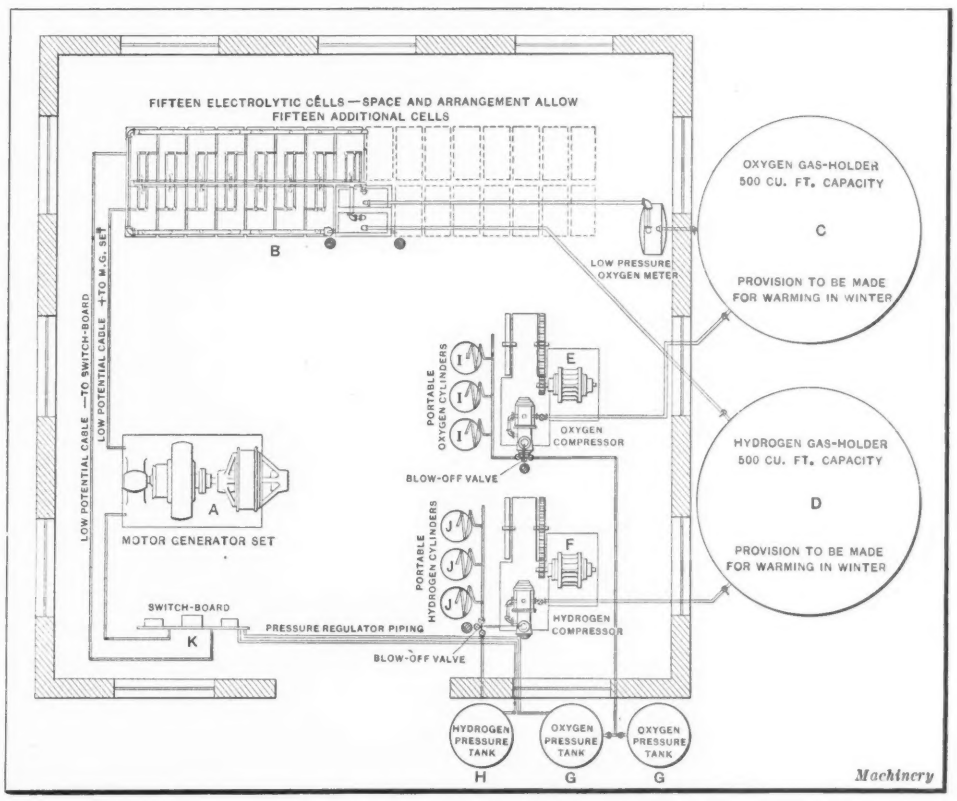

Fig. 12. Plan of Electrolytic Oxygen Plant

The presence of these sulphur and phosphorus compounds can be shown by a very simple test. Moisten a piece of white blotting paper with a 10 per cent solution of nitrate of silver and turn a jet of acetylene on it. If these gases are present, the moistened spot will turn black, and a rough idea may be obtained of the amount of the impurities by the rapidity with which the action takes place. Inasmuch as both sulphur and phosphorus, when present in more than very slight amounts, are injurious to iron and steel, it is necessary to provide for the removal of these gases from acetylene, if important welds are to be made. The importance of purifying generator acetylene is not realized in this country, although both in England and on the Continent purifiers are in quite general use. They are of comparatively simple construction, and it is believed that it is only a question of time until their use will be general in this country.

Sulphur and phosphorus compounds are not so injurious to other metals as to iron or steel, and as the quantities are small when good carbide is used, ordinary work is not seriously damaged. The dust carried over the gas consists very largely of lime, which has an exceedingly injurious effect on any steel or iron weld.

A yellow deposit on the lime residue indicates that the generator has been working at too high a temperature, and in fact, a dangerous one. It is not often that this is found.

Generators for Acetylene Gas

Fig. 13 shows the form of generator developed by the Davis-Bournonville Co. for use with its positive-pressure (often erroneously referred to as high-pressure) torches. In this generator the carbide is introduced into the hopper *A* through two filling holes at the top of the generator. As acetylene is an extremely inflammable gas, it must be handled with considerable care. The operation of acetylene generators has been made the subject of careful study in the laboratories of the fire underwriters. At present, the rules of the insurance companies require a generator to be operated under such conditions that the gas will be produced at the rate of 1 cubic foot per pound of carbide per hour. As a result, means must be provided for dropping the calcium-carbide from the hopper *A* into the water in the generator at a prescribed rate. This is accomplished by means of a clock motor which is driven by the counterweight *B*. This motor causes the rotation of a disk at the bottom of the hopper, and as the disk revolves the carbide is swept off by an inclined plate or vane.

With acetylene gas under pressure of more than two atmospheres — approximately 30 pounds per inch — there is danger of endothermic explosion; and to provide an adequate margin of safety, the pressure of the gas in the generator is not allowed to exceed 15 pounds per square inch. When the pressure reaches 15 pounds per square inch, the first one of these two diaphragms is distended, with the result that a locking device stops the clock motor and hence cuts off the supply of calcium-carbide. As a safety device, a second flexible diaphragm is provided which operates at a pressure slightly above 15 pounds per square inch. In case the first diaphragm should fail to work, the second one would rise and engage a locking clutch which stops the motor. In addition, a safety valve is provided at *C* which will blow off in the event of the pressure's rising above the required point. This safety valve is connected to a pipe which extends up above the roof of the generating house so that the acetylene may be discharged into the atmosphere. In this way all danger of explosion is eliminated.

Lump carbide, designated as the 1¼ by ⅜ inch size, is used in the generator. When this carbide is dropped from the hopper, it sinks to the bottom of the water in the generator, and as a result the acetylene gas which is liberated must rise through the full depth of water. Two advantages are secured in this way: first, the acetylene receives a preliminary

washing in the generator; and second, the heat produced by the chemical reaction of the carbide with the water is absorbed by the water so that the gas is passed on at a relatively low temperature. Upon leaving the generator, the gas passes into the pipe *D* which carries it to the bottom of the flash-back chamber *E*. This chamber is full of water and serves the double purpose of giving the gas a second washing and forming a water seal between the service pipe and the acetylene in the generator. After passing through the flash-back chamber the gas enters the filter *F* which is filled with mineral wool that serves to remove suspended impurities, and upon leaving this chamber the gas enters the service pipe *G*, from which connection is made direct to the torches. It is not within the scope of this article to give instructions regarding the operation of the acetylene generator, but the manufacturers issue a booklet in which complete information is given in regard to this branch of the welding and cutting industry. The generators are made in five sizes, with capacities for charges of 25, 50, 100, 200, and 300 pounds, respectively. One pound of carbide will produce 4½ cubic feet of acetylene, so that the different sizes of generators will produce 112, 225, 450, 900, and 1350 cubic feet of acetylene from a single charge. These generators are intended for use in shops where the acetylene is used direct from the generator, but the Davis-Bournonville Co. also makes a generator known as the "Navy" type, which is designed for use in connection with a compression plant for collecting the acetylene in cylinders for portable use, and acetylene can also be taken direct from the generator under pressure for use in the cutting and welding torches. In this type of plant, provision is made for drying the acetylene and removing the air from it preparatory to compression.

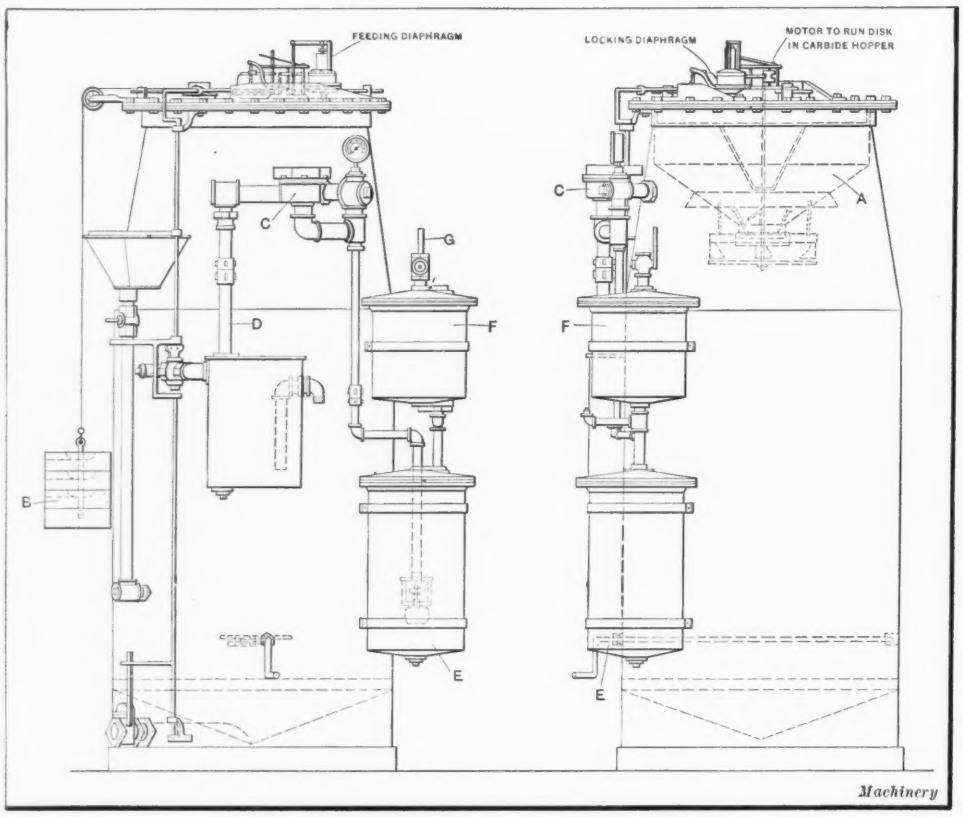

Fig. 13. Davis-Bournonville Acetylene Generator

The generators which have just been described are made for installation in a fixed position, but for some classes of work it is desirable to be able to move the source of acetylene about from place to place. To meet this requirement, the Davis-Bournonville Co. makes two styles of portable outfits which are shown in Figs. 14 and 15. In one of these, a two-wheeled truck is employed, on which are mounted an oxygen cylinder and a cylinder containing the acetylene gas. In the other style of portable outfit, an acetylene generator and a battery of oxygen cylinders are mounted on a four-wheeled truck. This equipment is made with either the 25-pound or 50-pound acetylene generator, and with a corresponding number of oxygen cylinders, according to the requirements of the plant in which it is to be used. It is often found convenient to use one of these portable outfits to avoid the necessity of moving heavy work, or for working in different places in large factories, where it is easier to take the torch to the work than to bring the work to the torch.

Fig. 16 shows the generator furnished by the Oxweld Acetylene Co. This is a low-pressure generator, used in connection with the company's low-pressure torch. The illustration, with the arrows indicating the flow of the gas, shows clearly the action of the generator. The apparatus to the left is the generator proper, while that to the right is the gasometer, used for storing the gas at low pressure.

Piping

Acetylene piping should be carefully designed, especially in regard to size. Frequently trouble is caused, particularly in the case of low-pressure systems, by having the pipe too small. The manufacturers of the equipment will give advice in this connection. Acetylene piping can be put together with ordinary screw joints and pipe grease; or other lubricants, such as red or white lead, may be used. It is better, however, to weld the pipe and insure in this way against leakage.

In the case of oxygen piping, no grease or oil whatever should be used, if it is put together with screw joints, as a lubricant should not be depended on to make a pipe joint in any case, but only to allow the threads to be easily screwed into place, the joint depending on the threads. Soap answers the purpose for oxygen pipe very well. It is, however, advisable, as in the case of acetylene piping, to weld the joints. Piping for both oxygen and acetylene should be galvanized. The ends of all pipes should be reamed out to make the pipe of uniform size throughout. Where piping is welded, no fittings should be used. Valves should be of the best quality and of sufficiently large area, particularly with a low-pressure system, to avoid reducing the pressure. After the piping is all erected, it should be tested to at least 100 pounds pressure per square inch, and leaks, if any, stopped. The best method of testing is with soap suds, brushed not only on the joints, but all over the pipe, as there are sometimes pin holes or slight defects in the body of the pipe.

Acetylene and Oxygen Tanks

Portable acetylene tanks are provided by the makers of acetylene gas, from whom they may be obtained on reasonable terms. The cost of the gas is about 2½ times that made in a generator, but this expense is warranted in some cases even for shop work, on account of the tanks costing less than the generator. Each case has to be considered separately. The larger the shop, the greater the advantage in the use of a generator. The charging pressure of these tanks is about 225 pounds per square inch, but this varies so much with the temperature that the pressure alone is no indication of the amount of gas in the tank. It is sometimes found that after working an hour or so, the pressure is equal to or greater than that at the start, due to the tank being warmer. Tanks should be kept in a cool place and the outlet capped to be sure that there is no chance for a leak.

Compressed acetylene should never be used at a greater rate per hour than one-seventh of the capacity of the tank. For instance, if a tank holds 300 cubic feet, 45 cubic feet per

hour is about the maximum rate at which the acetylene should be drawn. If it is necessary to use a torch large enough to exceed this rate, two or more tanks should be coupled together with manifolds which can be procured from the manufacturers of the tanks, or made in any good machine shop. A greater rate of discharge than that stated above results in some of the acetone being drawn out, which is liable to cause bad welds.

The Federal law requires that in shipping a tank containing oxygen, or a full acetylene tank, a label be pasted on it, colored green or red, respectively, and worded according to the instructions on the subject issued by the Bureau of Explosives, 30 Vesey St., New York City, from which copies may be obtained. Empty oxygen tanks need no label, but the bill of lading or express receipt should specify that the tanks are empty, in order to obtain the advantage of the lower freight rate. Empty acetylene tanks must have the red label removed before shipment and can only be shipped by freight. Any tank found to be defective should be tagged, and the manufacturers notified by letter. It occasionally happens that a valve cannot be shut. Such a matter should be reported to the manufacturers, and if the valve is found defective, they

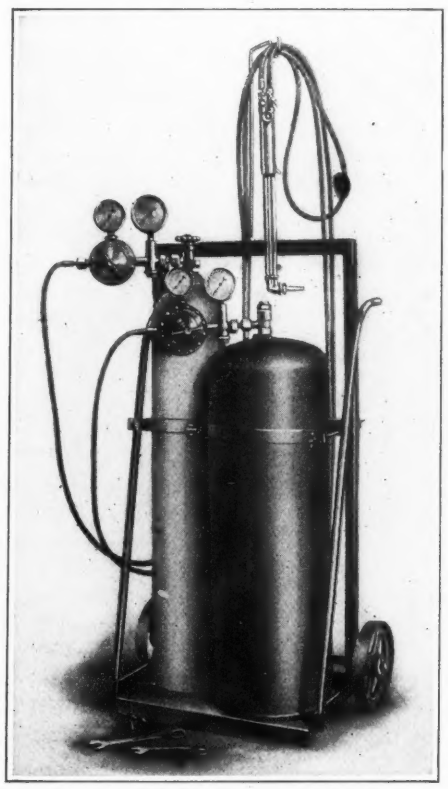

Fig. 14. Portable Compressed Acetylene and Oxygen Tanks

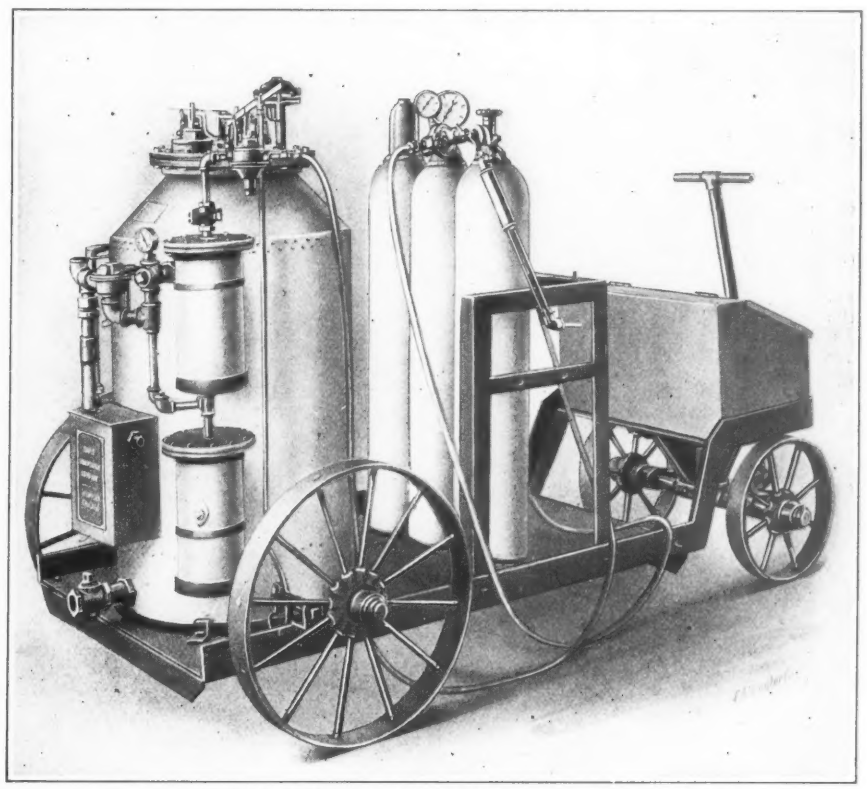

Fig. 15. Portable Outfit comprising Acetylene Generator and Oxygen Tanks

will make an adjustment for the amount of gas lost. All tanks, both oxygen and acetylene, are provided with safety disks or plugs. These are intended to prevent excessive pressure caused by heat or otherwise, by allowing the gas to escape gradually and thus prevent an explosion. In some cases these safety devices are so arranged that they are sealed to prevent tampering with them. If this seal is broken no adjustment will be made. Therefore, if anything goes wrong with the valve or disk, do not attempt to repair it, but return it in exactly the condition in which it was found. Of course, if an acetylene tank should leak, it should be placed out of doors to avoid danger of explosion. The percentage of such difficulties is exceedingly small.

Fire Risk

Chlorate of potash and carbide are both dangerous from a fire standpoint, and should be kept outside of the shop, preferably in a shed separated entirely from the building. Most, if not all, cities regulate the storage of these chemicals. If possible, a shop location should be selected away from a bad fire risk, such as a lumber yard, planing mill, cabinet shop, oil store, etc., as these automatically increase the insurance rate no matter how well the welding shop is protected. The installing of automatic sprinklers should receive careful consideration, particularly with a low roofed building, as the heat from heavy welding fires is great. Overhead wooden truss members and joists should have the accumulation of dust cleaned off at frequent intervals, as it is liable to catch fire from charcoal sparks. A coat of whitewash, using the acetylene generator residue, is a good thing to keep sparks from catching, as well as being of considerable assistance in lighting the shop. Charcoal fires should be kept covered with asbestos paper to hold sparks down. It should be remembered that even if the fire insurance were paid the day after the fire, there would be a great loss from not being able to do business and that, therefore, all precautions should be taken. Insurance should be considered as a protection against the mistakes of others, and not as a license to be careless. If everyone would act as if no insurance could be collected for damage caused by his own carelessness, there would be fewer fires, and insurance rates would not be as high as they are.

Eye Protection

Dark glasses should always be worn while welding, as one's eyes are liable to be injured, particularly by the intense glare from the flux used in welding cast iron. For cast iron, very dark glasses, with a greenish tinge, are most suitable. For other metals, lighter colored glasses are better, as they permit a clearer vision of what is being done. In any case, glasses are dark enough, if immediately after welding it is possible to see clearly, without being bothered with white spots in front of the eyes after taking off the glasses.

Machine Tool Equipment for Welding Shops

The machine tool equipment to be provided will depend upon circumstances. For a shop where welding alone is done, the following should be provided: 24-inch upright drill; floor stand; two-spindle emery wheel for 10-inch wheels; flexible shaft grinder with 6-inch wheel. These tools can be driven by a small electric motor, if current is available. Any other motive power can be used, although a gasoline engine should be carefully installed to avoid fire risk. The author permits no gasoline in his shops under any pretext whatever.

For a large shop, or where a good machine shop is not available, it may be necessary to install more machinery. The following additional tools will cover practically everything necessary: Lathe, 20-inch swing, 4 feet between centers; lathe, 30-inch swing, 8 feet between centers; planer, 36-inch by 36-inch by 6 feet; pillar shaper, 12-inch stroke; horizontal boring mill, 4 feet between heads; 3-foot plain radial drill.

These tools must be accurate, but as there is no question

of production in quantity involved, they may be of light and simple construction; for instance, it is not necessary to have quick change-gears on the lathes. All such expense should be avoided. Very careful thought should be given to the machine tool equipment. It is expensive, and unless enough work is done, it will not pay to install it, but it will be cheaper to do the work with hand tools, or even send it to a shop at some distance.

The real cost of operating a machine is frequently underestimated. Interest, depreciation, repairs, insurance and taxes have to be paid, even if not charged in the operating expenses. Taking the sum of these items at 15 per cent per year on the cost of a machine, and assuming the installed cost at $2000, there will be a monthly expense of $25 against the machine. If it is operated 200 hours per month, the hourly expense will be 12½ cents; if it is used only 20 hours per month, the hourly expense will be $1.25. It is evident that no ordinary charge for work, say 60 or 75 cents per hour, will cover the latter expense, which is exclusive of labor, power and supplies. Each case is a law in itself, and all that is urged is that careful and intelligent consideration be given, to avoid financial loss.

Other Equipment

It is generally necessary to heat pieces before welding to obtain a sound weld as well as to economize in the gases. For this purpose, plain blacksmith forges are the most convenient for small work. Their tuyeres should be level with the bottom of the pan, which should be of cast iron. The pan should measure about 23 by 36 inches inside and about 4 inches deep, which will allow the bottom to be lined with 1-inch thick firebrick, laid in fire-clay, and still leave the sides high enough to keep the fire off the floor. The simplest fan drive is good enough, as it is never used except in starting the fire. It is well to have plenty of forges, as a good welder on moderate-sized work can keep two or three busy without any difficulty.

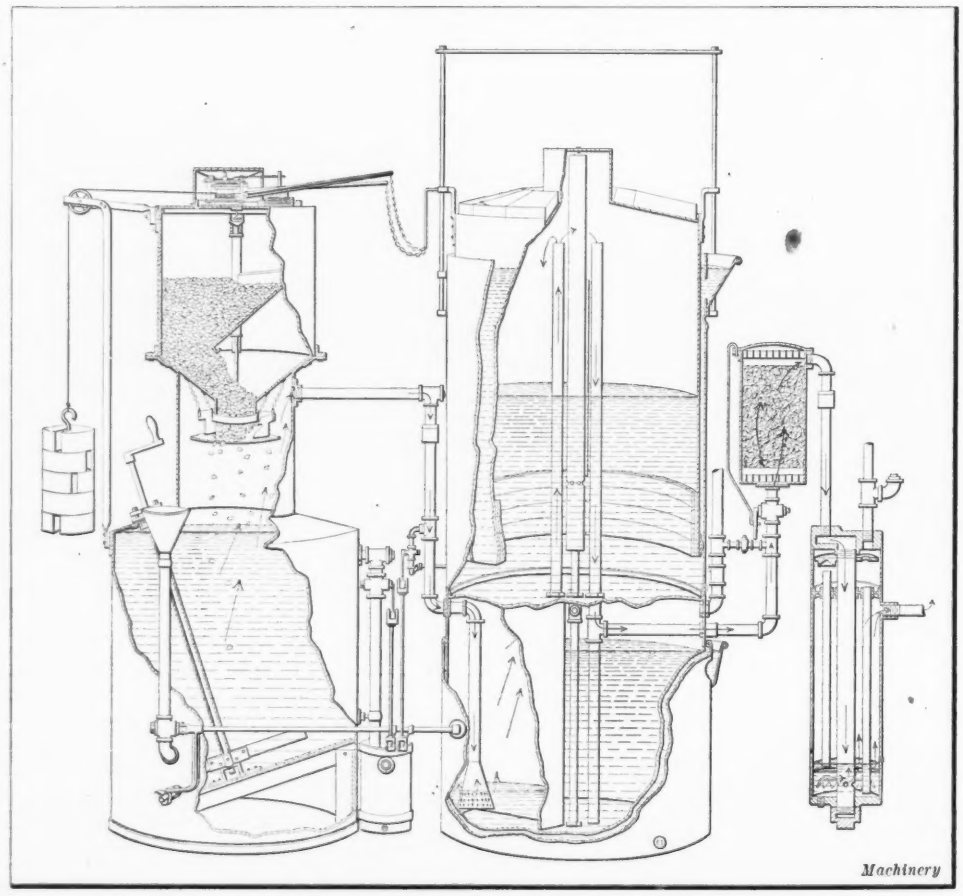

Fig. 16. Oxweld Low-pressure Acetylene Generator

For heavy work a concrete or brick floor is necessary; this, if of concrete, should be at least 6 inches thick, laid on a solid foundation of cinders that should be free from coal and well rammed; and proper provision should be made for drainage. The concrete may be a rather lean mixture, but should have a top dressing ½ inch thick of a rich cement mortar. The floor should be about 10 feet by 15 feet or 12 feet by 12 feet, preferably the former, as it is more convenient for a number of fires. Over the floor should be some kind of hoist of a capacity of about 3 tons, which will handle almost any work that can be brought into the shop. The kind of hoist depends upon the circumstances, such as the construction of the building, space around the floor, etc. A jib crane is very convenient, but expensive. If the roof trusses are strong enough, an I-beam extending between them and carrying a trolley and chain hoist is ample and cheap. If the floor of the building is of concrete, be sure that it is heavy enough to stand considerable heat. Of course a fire should never be built directly on the concrete. A layer of firebrick can be placed under the entire area to be covered by the fire, and the piece laid on this raised enough to get the fire in place; or plates of cast iron or steel can be laid on bricks to give air space underneath and the fire built on the plates. Cast-iron plates 1 by 3 feet are best. They should have 1-inch holes cored in them about 6 inches apart for draft, and when setting up, they should be left slightly apart for the same reason. Angle-plates of the same general design may be used for walls instead of bricks, and in some cases are very convenient. They should not have any holes in them. They radiate more heat than bricks, but do not fall over so easily. Some of them should be 18 inches long for small fires.

Firebrick will also be needed for holding the fires in place on the forges, and for use on the floor. Hard-burned brick, while not so good for the regular purpose for which firebrick is used, is better for this purpose, as it does not break or chip so easily in handling.

Examples of Equipment

Fig. 17 shows a cast-iron table 30 inches wide and 60 inches long. It is planed on the top, bottom and all edges, and has a support made of old ¾-inch pipe welded together. It is 26 inches high from the floor, which is found to be most convenient, as small work can be done by the welder while sitting, and for large work, such as rear axles, rear axle housings, cylinders, etc., which have to be tested, and which are frequently set up high on blocking, is not too high for convenience. Another view of the table is shown in Fig. 18, which also shows an angle-plate that is very convenient. It will be noticed that the rib *D*, which is ¾ inch thick, extends on two sides of the table, while the other two sides are provided with a flange *B*. As stated, all of these edges are planed. This permits of clamping pieces vertically or horizontally, as the case may be, and has been found to be an exceedingly convenient arrangement.

Fig. 17 also shows what was originally designed as a jig for welding crankshafts, although it has been found that it is a valuable appliance for many other purposes, particularly in welding bars, tubing, etc., that must be kept straight. It is shown at *C*. The V-blocks are provided with tongues which slide in the groove *D;* the slots *E* and *F* are at unequal distances from the groove. This is done to insure proper setting of the V-blocks. The base is planed on top and bottom, and after the bases of the V-blocks were machined, they were bolted in place and the V's in the top of them planed at the same time to insure absolute alignment. The V-block caps have the holes for the studs drilled ⅛ inch large, so that there will be no difficulty in clamping when screwed down

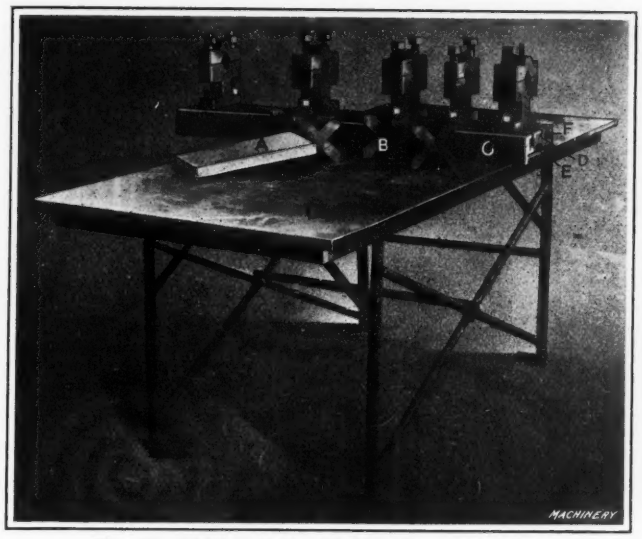

Fig. 17. Welding Table, Welding Jig, and V-blocks

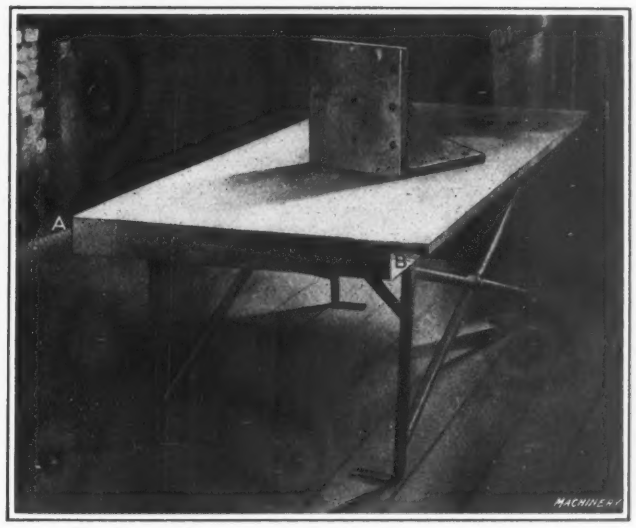

Fig. 18. Another View of Welding Table and Angle Plate

on a round piece. The base of this jig is 10 inches wide and 36 inches long. The V-blocks are of different thicknesses, the wide ones being 2½ inches and the narrow ones 1½ inch. This permits of getting into corners, which is sometimes desirable. There are also shown a plate of graphite at *A* and a set of ordinary V-blocks at *B*, which are better shown in Fig. 19. Two sets of these are useful for holding shafts and similar pieces that must be kept straight in welding, and will be found of advantage for many other purposes. The six V-blocks should be made from one casting, first planed and then cut off to the required thickness. Each one of a pair should be planed to the same thickness, and the 1- and 1½-inch sizes together should have the same thickness as the 2½-inch size. The grooves should be planed in the casting before cutting off, to enable the blocks to be placed in the same line as when originally planed, it being difficult otherwise to plane the V's exactly symmetrical. The various devices shown in these two illustrations make it possible to take care of almost any shape that must be kept square or in line.

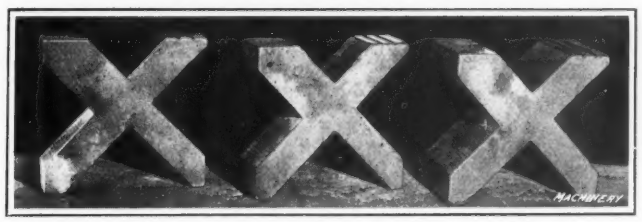

Fig. 19. Set of Cast-iron V-blocks of Different Thicknesses

A kerosene-oil burner can, in many cases, be used for heating large articles in which contraction strains will not cause any trouble, and is useful to have in a welding shop.

The general tendency in a shop of any kind is to allow bars, mandrels or similar material to lie around in corners or under the bench where they are difficult to reach, and frequently damaged. A rack for such parts, shown in Fig. 20, is safer, and improves the appearance of the shop. This rack is about 5 feet long and 3 feet high, and is made out of old ¾-inch pipe welded together. On the right-hand end is shown a device which in its different forms is frequently of service in preventing the melting of babbitt bearings. It cannot be used in all cases, but where there is much work of one kind to be done, it pays to use it. This particular device consists of cold-drawn steel tubing about ⅛ inch thick and of proper outside diameter to fit the bearings of the Ford automobile cylinder block. When it is necessary to do any welding on one of these cylinders, this piece is clamped into the bearings just tight enough so that it will not turn readily, and filled with water. The ends shown hanging down stand up straight. Any change in the position of the cylinder in the fire can be taken care of by keeping the legs upright. It is necessary to watch the water carefully so that it does not evaporate.

Fig. 21 shows the use of the cooling apparatus for preserving the babbitt bearings in the upper half of a Ford crank-case. The illustration shows the device held in place by wires. This was found at the first trial to be unsatisfactory, as it did not hold the pipe in contact with the bearings closely enough, and at the present time bolts and ¼-inch pieces of steel are used to overcome the trouble.

Miscellaneous Equipment

A substantial work bench with one or two vises should be provided. If two vises are provided, one vise should have jaws 5 inches wide, for general use; the other may be a second-hand one, to be used for holding pieces while welding, when they cannot be easily blocked up so that the welder can reach all parts of the weld. The good vise should never be used for welding, as the heat will in the course of time draw the temper of the jaws. Of course the total number of vises

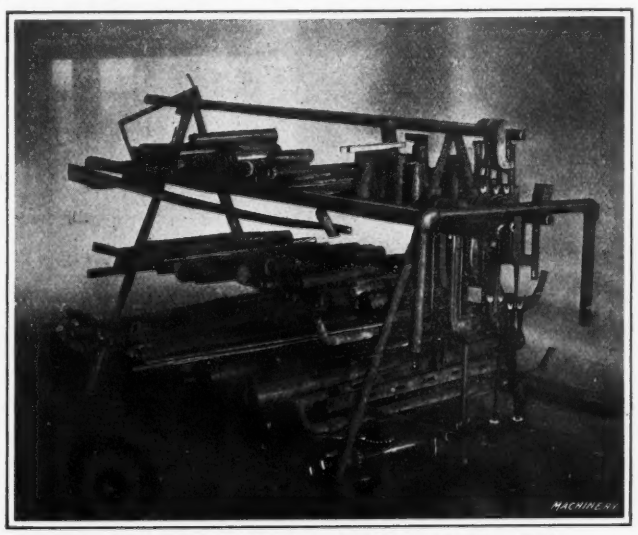

Fig. 20. Rack for Mandrels, Blocking and Other Tools

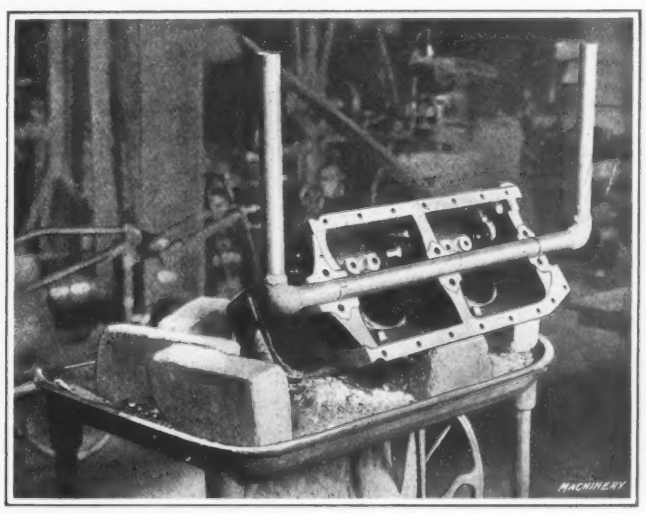

Fig. 21. Pipe Mandrel used to prevent Melting of Babbitt Bearings

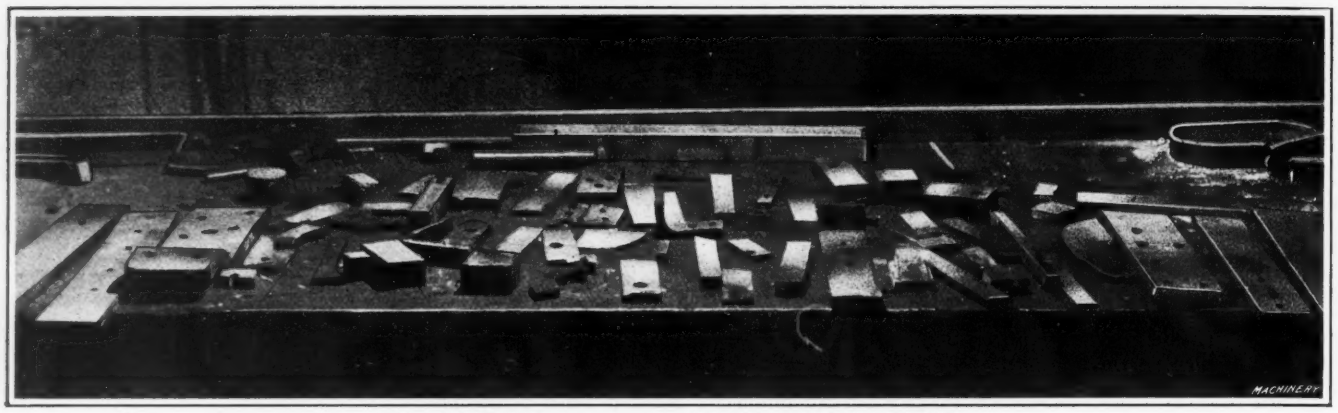

Fig. 22. Miscellaneous Clamps and Blocking required in Welding

and size and number of benches will depend on the number of welders employed. For four men, one old vise and two good ones will be enough; the bench may have a length of about 25 feet, or three small benches may be used. Several pairs of "pick-up" tongs for handling bricks and other hot objects, and gas pliers 10-inch and 13-inch sizes for use around the forges are necessary; their screwdriver ends should be ground off or bent over to make them safe when lifting with the end toward the face. The sharp end has caused bad injuries. As soon as the jaws become slippery, the pliers, should, of course, be thrown away.

In many cases, especially where the pieces are of cast iron, and heavy, or where lugs or projections have to be built higher than the adjacent surfaces, time will be saved by building a dam of some refractory material of the proper shape, and melting the metal into it. The best material for this in the case of cast iron or steel is a graphite mixture, such as is used in crucibles. This can be obtained in blocks of any size and shape, by ordering it specially; but rectangular blocks from ½ inch thickness up, and round rods of various diameters, for use in keeping holes from filling up, are stock sizes, and can be obtained on short notice from crucible manufacturers. An assorted stock will be of great aid in quick work. In using this material, it will be found advisable to have it in position while preheating. It is more or less porous, and when covered over during the welding, the heated air coming from the pores will cause pin holes, as it has no other way to escape than through the weld. Preheating the graphite expels some of the air and leaves less to cause trouble; but if a smooth, thoroughly sound weld is required, it will be necessary to turn the piece over, remove the graphite, and melt the metal until the blowholes are eliminated.

An assortment of C-clamps, with from 3- to 10-inch opening, is needed for clamping work together or to the table; also two

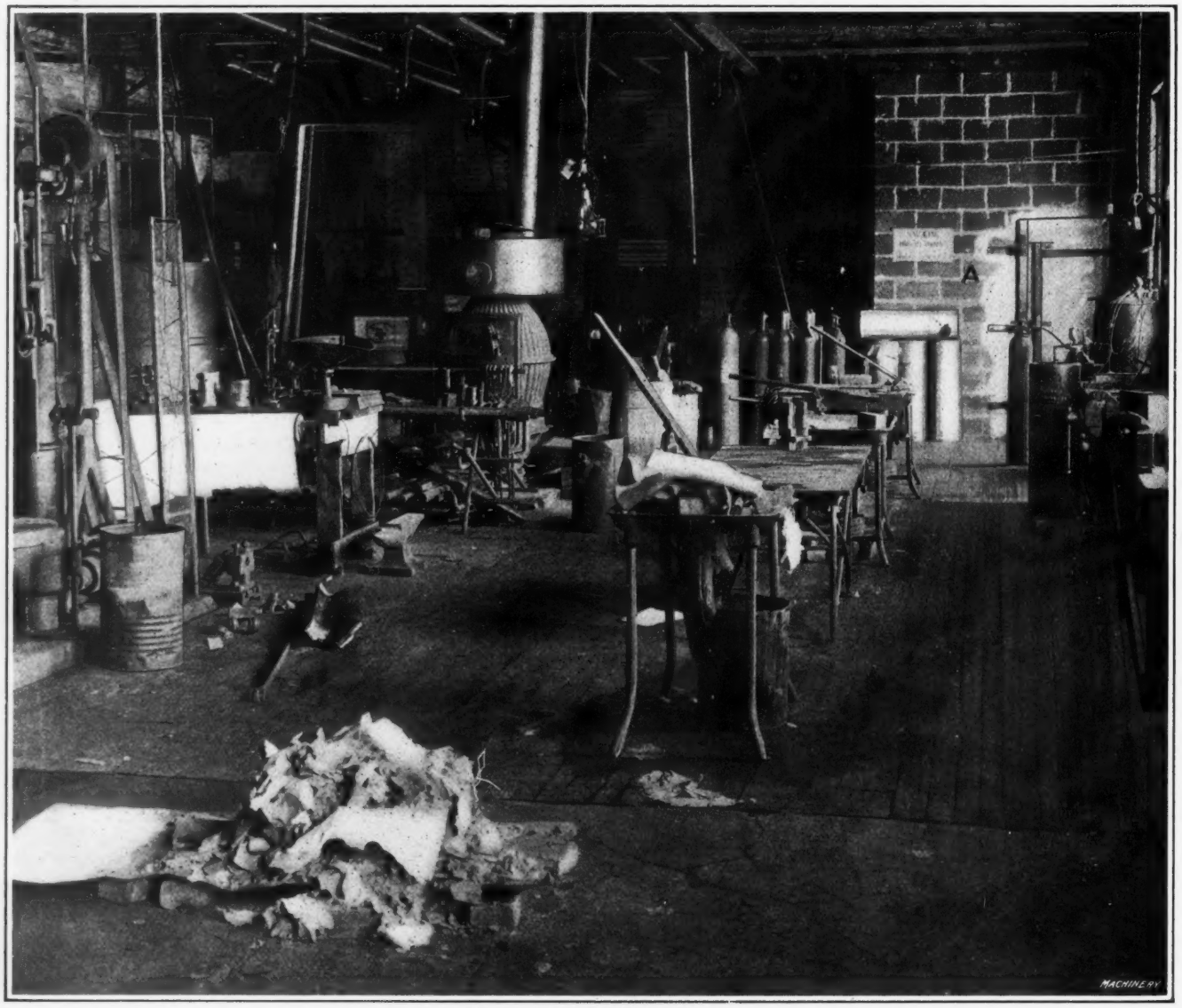

Fig. 23. View of Welding Shop

bar clamps taking in about 30 or 36 inches, such as are used by carpenters; these are handy for long work. Of course the regular metal-working hand tools will be needed, such as hammers, chisels, files, hack-saws, calipers, squares, straightedges, surface gages, etc. A number of cold-rolled steel bars, about 30 inches long, and of various diameters, are of great assistance in lining up automobile crank-cases and other parts. They may be obtained as they are needed.

A collection of pieces of scrap of various sizes and thicknesses for liners, as shown in Fig. 22, is necessary for lining up. The thicknesses will range from a piece of tin to 2 inches. The thicker ones should be of cast iron, to avoid injury by heat. It is also of advantage to have some of the thicker pieces in pairs and planed to the same thickness. These pieces should not be exposed to great heat, to avoid warping them. They are of special advantage in blocking up pieces with finished surfaces.

Asbestos building paper is used to protect the welder from the heat; to confine the heat to the piece being heated; to keep drafts off a casting that has been welded, which without such protection would tend to crack; and after it has been broken up so small as to be useless for these purposes, it is valuable for packing cylinders, etc., to allow them to cool uniformly. This material comes in rolls of about 100 pounds and in thicknesses varying from 6 to 12 pounds per 100 square feet. The 8-pound material is heavy enough for general use.

Plaster-of-Paris Patterns

Some knowledge of patternmaking is very helpful, especially where pieces of some size are missing. It is expensive to fill up such places with the torch. If a pattern can be made to fit, its use will make a cheaper and better looking job, particularly if the surface is irregular. Even if the pieces are not missing, but are many in number and small, so that the total length of welds would exceed the length of the weld required if a single casting were used for the repair, it generally pays to make one. Plaster-of-paris is the most convenient material to use for patterns for this purpose. Wooden patterns are very expensive, and unless they are simple, and a number of castings are to be made, are out of the question.

It requires some experience to handle plaster-of-paris successfully, and it is impossible to lay down rules for its use that will fit all cases. Therefore, the following suggestions will not always apply, and good judgment and ingenuity will have to be used:

Do not mix the plaster too dry, or it will set too soon.

Do not mix too much at once, but have several batches ready to mix one after another, if a large quantity is needed.

Prepare the piece by chipping or in other ways, so that the pattern will come out easily.

Make the shape of the pattern as simple as possible, by cutting out irregularities around the sides. The sum of two sides of a triangle is always greater than the third side, and cutting off angles, of course, means a saving in welding.

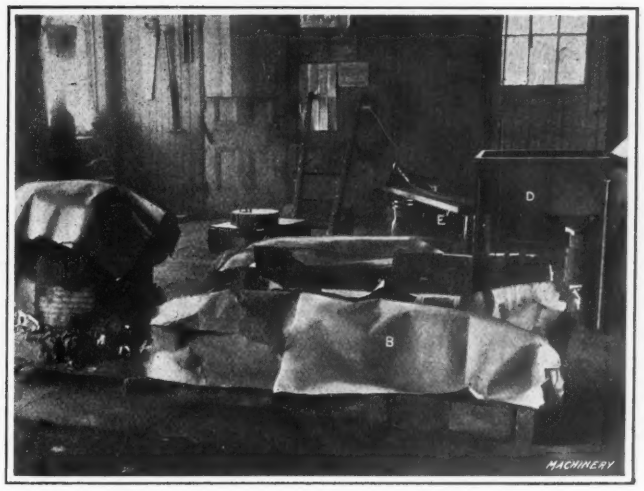

Fig. 24. Preheating Floor for Building Fires

Bevel the edge of a cast-iron piece before pouring the plaster-of-paris, and bevel the edge of the pattern before taking it out; it comes out more easily and saves preparing the casting.

Do not bevel too much, but leave enough so that it can be fitted tightly in place. This helps in less contraction of the weld. The fit need not be perfect, but the better it is the better the job will be.

In the case of aluminum, fit well, but do not bevel unless over ⅜ inch thick, and then leave about ¼ inch bearing, as aluminum crushes easily when hot, and there should be bearing enough to force expansion without crushing, if possible.

Have the molder rap the pattern well; the shrinkage of cast iron in casting is ⅛ inch per foot, and of aluminum 7/32 inch per foot. In the case of large patterns it will be necessary to add the needed amount to the proper edges and surfaces to allow for the shrinkage, and enough more to permit of any finishing that may be necessary.

General Shop Arrangement

Fig 23 shows one of the author's shops. The arrangement is not ideal, because there are windows only on one side of the shop which leaves considerable floor space that cannot be utilized. The arrangement of the forges and welding table should be noticed, particularly with reference to the work bench. In arranging a welding shop, the welding table and forges should be located near a good light, preferably daylight, so that the lining-up of work can be done quickly and accurately.

Old carbide cans are used under the forges to catch the ashes from the charcoal fires. These cans are kept partly full of water all the time. Before closing at night, the wooden floor around the forges is well soaked with water.

The acetylene generator room *A* is built in accordance with the underwriters' requirements and has a standard fire-door. No light, except daylight, is permitted in the room, nor is there any opening except one window and the door into the shop. It would be preferable to have the door opening from the outside of the building into this room, but in this case it could not be so arranged. The work on the concrete floor shown in the foreground is reached by the use of long hose extending from the regulating valves on the wall.

Fig. 24 shows the concrete floor on which the heavy welding is done. In certain cases, as for instances, when a large number of cylinders are to be repaired, and the forges are in use for other work, special fires, as at *B*, are built on it. Of course such fires are not built directly on the floor, but on sheet-iron or cast-iron plates which rest on bricks. There are four cylinders of various sizes in the fire *B*. At *D* is a home-made furnace lined with firebrick 1 inch thick on the bottom and sides which is used for preheating. Its dimensions are 25 by 21 by 10 inches, and the top angle-iron is 34 inches from the floor. A better size is 42 by 21 by 12 inches deep. A furnace of these dimensions would be large enough to handle the largest "six-in-block" cylinder made.

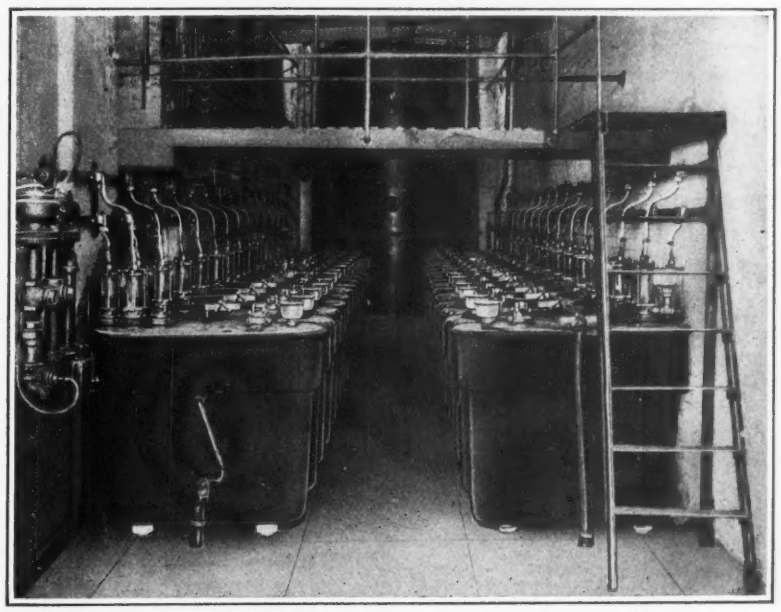

Fig. 25. International Oxygen Co.'s Apparatus for making Oxygen

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OXY-ACETYLENE WELDING AND CUTTING

In this number begins a series of articles on oxy-acetylene welding and cutting which will cover the subject thoroughly and be of great value to those engaged in this kind of work. The author of the articles, who has conducted a successful oxy-acetylene welding repair shop for over five years, has endeavored to describe the principles in general use on repair work. Photographs are invaluable aids to description, and a large number showing actual operations will be included—all of work done successfully in the author's own shops.

It should be understood that even a man who is fairly expert with the welding torch may find it difficult to prepare or preheat a repair job which is different from any with which he is familiar. Even with wide experience, it is not always possible to say off-hand how a piece of work can be best handled, and often the desired results cannot be obtained at the first trial. The beginner is therefore sometimes discouraged because he does not obtain satisfactory results; but he should persevere. In acetylene welding practice, progress is slow, and it is best to undertake at first only such work as a novice is fitted to handle, until the operator gains sufficient experience to warrant him in undertaking more difficult work.

The experience of the author in the oxy-acetylene welding field has been unusually extensive, but having been mostly on repair work he has written for those engaged in a similar line. Little mention will be made of the many applications of the welding torch in manufacturing work, as these applications are special in each case, and sometimes require a great deal of experimenting before success is attained. Most of the work so far done with the oxy-acetylene welding torch has been on repairs, and while descriptions have appeared from time to time in the mechanical journals of repair work, they represent isolated cases, and not complete repair work practice; so this treatise will fill a gap in existing mechanical literature.

In this series time and cost data have been purposely omitted, because in the present state of the practice it is not possible to give accurate data on repair work. Two good welders working on repairs of a similar character will often vary as much as 50 per cent in the time consumed, and as shop conditions also vary to a great extent, it is almost impossible to give accurate figures regarding costs.

NEW AMERICAN INDUSTRIES

When the European war broke out, few manufacturers realized what the effect of the stoppage of commerce between America and Germany would be; but soon the full force of the embargo laid on many German manufactured products was felt, and consternation reigned. It was impossible to obtain supplies from abroad, and conditions in this country did not seem to warrant the establishment of factories for the manufacture of chemicals and other supplies formerly obtained from Europe. It was feared that if the war ended suddenly the "infant" industries established here would perish, because our markets would be again supplied with foreign products at prices much lower than American manufacturers could compete with.

The war has lasted over a year and its end is not yet in sight, so American manufacturers have taken courage and have established factories for producing many of the supplies formerly obtained abroad, and in many cases are making big profits. Last July the market price of picric acid was forty cents a pound; now it is $1.70. Before the war began the price of carbolic acid was seven cents a pound; now it is $1.35. Prices of metals have increased from 25 to 100 per cent. As a result of these unlooked for changes during the past year the great steel companies are planning to produce raw materials and by-products which formerly were purchased abroad to the extent of hundreds of dollars annually.

The effect of the war doubtless will be to give the industrial life of America a great impetus, and to make it more independent of foreign supplies than it was before. It will tend to develop here a class of industrial experts such as has flourished in Germany. But this must be done without expecting that a high tariff will be created for protection. This country is too great, and its tendencies are too well defined in the direction of freer trade, to permit it to revert to the high protective tariff policy.

* * *

THE THEORIST AS A FACTOR IN PROGRESS

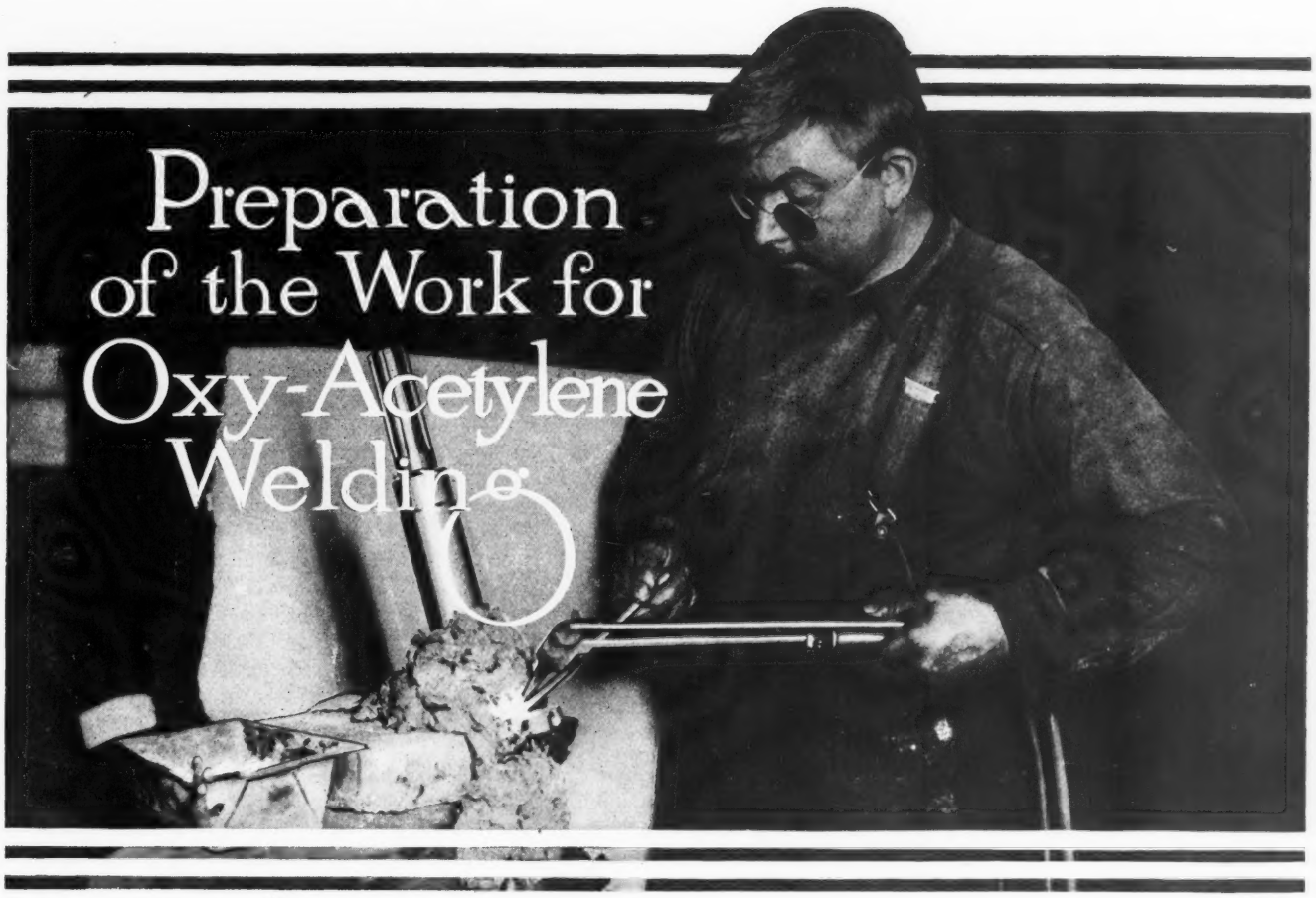
The so-called "practical man" often sneers at the impractical ideas of the theorist; and just because he has sneered so much and so long at the man with a theory, he is today doing his practical work in much the same way as it was done a quarter of a century ago.

"The practical man," says one of the most brilliant and original of the investigators in the machine tool field today, "is a man who knows the limitations of doing certain work in a certain way; but he does not endeavor to exceed these limitations, because he knows from experience that he would meet with failure; and he does not inquire into the whys and wherefores of the limitations. He does not concern himself with the reason for the heating of a cutting tool beyond the limit of endurance, for example, when a certain cutting speed is exceeded. He accepts facts as they are presented."

Now the theorist comes along and says: "There must be a reason for this limitation. If I can *find* the *cause* I may be able to overcome it." So he sets out to think along new lines, not merely accepting the apparent results of past experience. He thinks out a new way of doing the same work, so as to avoid the causes that created the practical man's limitations. He broaches his new idea, and the practical men are likely to join in saying: "He is too impractical. He hasn't had experience. Whoever heard of anyone trying to do this work in such a way before?" If the man of theory—that is, the man of a new idea—has no influence to make himself heard, that is the end of it; but if he has a chance to experiment, to try out his ideas, the result in the end is often a complete reversal of practice. After having been shown, the practical man adopts the *new theory*, calls it *good practice*, and holds on to it tenaciously if anyone attempts a change.

The practical man believes that there is "too much theory." As a matter of fact, there is too little. The theory of yesterday is the practice of today, and the more assistance we can enlist from theory today, the better practice will we have tomorrow.

Preparation of the Work for Oxy-Acetylene Welding



IT is generally essential that a weld be made through the whole section of a break. Sometimes this is not necessary, and in exceptional cases it may be impossible; for instance, in the case of a break through the eye of a cast-iron piece, where the diameter of the hole is small, compared with its length, it is generally impossible to reach all of the crack with the torch from the inside of the hole, and there is danger of producing hard spots, which cannot be removed except with special grinding machinery that is not usually available. In such cases extra caution must be used to insure a satisfactory job.

For ordinary work it is sufficient to bevel the edges of the broken parts so that when placed together the included angle will be 90 degrees, and so that just enough of the old break will be left to enable it to be correctly set up for welding. The reason for opening the break to a 90-degree angle is to permit the flame of the torch to get to the bottom of the V, so that the metal may be melted thoroughly and the natural bridging effect of the melted metal, with the resulting imperfect weld, may be avoided. It is not unusual for even an experienced welder to find such an imperfection in one of his welds, particularly if it is a rush job; and it is one of the difficulties a beginner must carefully avoid, particularly if the piece can be welded from one side only, as is frequently the case. In such cases the crack must be entirely burned through with the torch, even if drops of metal remain hanging under the weld.

It is especially important that the 90-degree angle be maintained in preparing steel. This metal sets so rapidly that the bottom of the weld will be full of cold shuts, or a great amount of time will be lost and gases wasted in burning away metal to get a good weld, unless the beginning of the weld is made easy to reach. It is also advisable, particularly with torches having comparatively light tips, to have plenty of room for the flame to spread, and avoid burning the tip.

A very good way of preparing parts where there is not sufficient room for a 90-degree angle, and also for heavy welds, by which a considerable saving of gases and time may be accomplished, is to drill out the bottom of the crack with a ⅝-inch drill and bevel the sides to less than 90 degrees. This applies to both steel and cast iron, and is especially useful when the break is in a corner, where it is evident that a 90-degree angle cannot be obtained. This method also frequently reduces the time of preparing the work, as with cast iron the remainder of the V can be easily removed with a sledge and handle chisel.

The piece should always be prepared from both sides when possible, resulting in a double V, as shown in Fig. 1. It will be evident, upon a little consideration, that this needs only half the welding that a single V does, besides which, it tends to produce a better weld. A crack remaining in the center of a piece is not nearly as dangerous as if it were on the outside, and the shallower the V, the more readily is a good weld made.

Any method of making the V is allowable, the object being to open up the V well, and to permit of making the best and easiest weld. For small pieces of any metal, an emery wheel is probably as good as any. Cold chisels and sledges or hammers are excellent for cast iron, where the piece will stand their use. In some cases a hacksaw is most useful. Drilling along the crack and chipping out the bridges roughly is a good method where the piece is cracked and not broken. The drill should be ground to an included angle of the lips of about 120 degrees, and the point of the drill should just go through the metal. If it goes too far, there will be trouble on account of the bottom of the hole burning through too quickly, especially if a heavy tip must be used. The diameter of the drill should be about equal to the thickness of the piece to be welded.

There is one method which is of much assistance in such cases, for example, as that of a large pipe or pipe fitting flange broken off at the root, where the body of the casting is not very thick, say ¾ inch. A fitting, such as an elbow, must be kept in a fire to avoid cracking and is awkward to turn while red-hot, as well as hard on the welder. The part being welded would ordinarily be above the fire by an amount equal to about the diameter of the flange, which would allow it to cool rapidly, making welding difficult and probably resulting in a cracked casting when cooled. If, however, the inside of the crack be chipped out to the regular V

half way through, and the outside edges left nearly parallel, and about ⅛ inch apart, leaving a few narrow parts of the old crack to line it up by, the elbow can be set with the flange downward in the fire and allowed to remain there until the outside is entirely welded. This is easily done by playing the flame between the parallel sides of the crack, which, as they confine the heat closely, soon become melted, and run together at the bottom, with careful handling of the torch; after this, sufficient metal is added to complete the outside of the weld. It is then an easy matter to weld the inside, as the part worked on can be in the fire all the time.

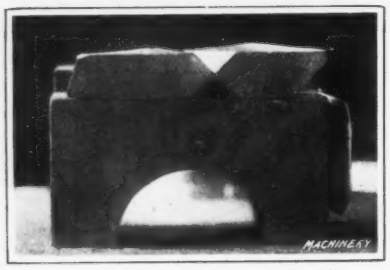


Fig. 1. Work beveled from Both Sides

It is sometimes best not to bevel the edges of the pieces. This is true of thin pieces, where it is unnecessary. In the case of cast iron and steel, pieces ⅛ inch thick or less can be welded without making the V. In aluminum nothing less than ½ inch thick and in brass and bronze nothing less than ¼ inch thick should be beveled. These rules are only approximate and experience will determine what should be done. At the beginning, it may be best to bevel everything with the exception of very thin pieces, except in aluminum.

Sometimes it is best to burn out the crack without beveling it. This is true of an irregular piece, not very heavy in section, on which there are no finished surfaces that can be used for lining up, and which has to be lined up true by the crack. It should not be forgotten that burning out is expensive and should not be resorted to unless necessary. The metal is melted with the torch, and pulled out with the welding stick, until the V is made, when welding proceeds as usual.

It requires considerable ingenuity sometimes to prepare a piece, especially a heavy one, with an irregular break, so that a minimum of handling will result, as it is neither desirable nor comfortable to handle a heavy red-hot piece. After it is once set up, it is sometimes dangerous to turn a heavy piece over, as the weld may break, or a sudden draft may crack it outside of the weld. The author has seen many pieces where the first consideration in preparing has been ease of handling while hot, and the cheapness of preparing has been a minor matter.

Handling Heavy Hot Pieces

It is well to speak here of handling heavy hot pieces; they have frequently, even with the best preparation, to be turned over or moved during the welding. It does not do to be at all uncertain of what will have to be done at such times; and it has been found very helpful in case of doubt, to put the cold piece through the motions that are thought to be advisable when welding, using chains, hoists, bars, rollers, etc., just as if the piece were hot. The temptation to use the hands on the piece in this test must be carefully avoided. This trial shows what changes, if any, should be made in the plans, and also has the advantage that all tools used may be laid together till needed, and great loss of time and temper avoided by not having to hunt for them while under stress of work. It would appear, therefore, that before starting a job, careful attention must be paid to planning, as the preparation has a very important bearing on the quality, speed, ease and cost of the work.

General Remarks on Preparation for Welding

After the piece is beveled, it is necessary to set it up so that it can be readily welded; the method of preparation will have an important bearing on this, sometimes deciding the question. Other things being equal, the piece should be set with the weld on top, so that the melted metal will not run away. It is easy to weld steel on the side or even on the bottom of a piece, and cast iron, brass and bronze may also be so handled by an expert welder; but it is more difficult to produce as good a weld, and some metal is lost, making it a slower and more expensive process. Aluminum can also be so welded, being nearly as easy to handle as steel, but it is seldom necessary to resort to the practice.

Next in importance to a sound weld, and even sometimes more necessary, is the need of so welding the piece that it has such finished surfaces as required in line. Of course it is not possible in all cases, and is difficult in any case, to produce a perfect condition. In some cases, allowance must be made for machining. No rules can be laid down; but sometimes metal can be added so that the part can be machined to the original size; sometimes machining may be done without adding metal. Sometimes the metal may be heated and sprung or peened into place, or this may be done cold. Steel may be so treated, either hot or cold, depending on the nature of the piece; aluminum, brass, bronze and malleable castings must be peened or bent cold; cast iron cannot be so treated, but may sometimes be bent or straightened by clamping one end on the table, heating with the torch to nearly the melting point, and pulling down on the other end with another clamp very slowly.

Warping or Cracking

Warping or cracking is caused by the expansion and contraction due to the heat of welding. It is not possible to avoid these conditions, and they, therefore, must be controlled by making allowance for them. The principle of control is best illustrated by a simple test, as follows: prepare two pieces of cast iron as shown in Fig. 2 and bolt them tightly to some heavy piece of metal; the sides of the holes should bear against the bolts and the bottom edges of the V just touch. The heavy piece to which the smaller pieces are bolted is kept from being expanded by the heat from the torch, by putting it in water or by some similar method. Then make the weld, using no more metal than enough to fill the V and doing the work as quickly as possible, but being sure to burn through the bottom so that the weld will be sound. On cooling off, the piece will invariably break somewhere, and there will be a gap between the pieces which in the case shown amounted to 0.011 inch. If the piece the work is bolted to is not rigid enough, or the fit of the bolts against the holes is not tight, or if there is a trifle of spring in some of the parts, a light tap on the piece may be necessary to cause it to break; but the gap will always be there after breakage. If another test piece be made, and the ends left free, there will be no difficulty in making a satisfactory weld. Again, if the bottom edges of the V are butted together, the ends of the piece will rise, which is only another manifestation of shrinkage, as the metal on top is hotter than at

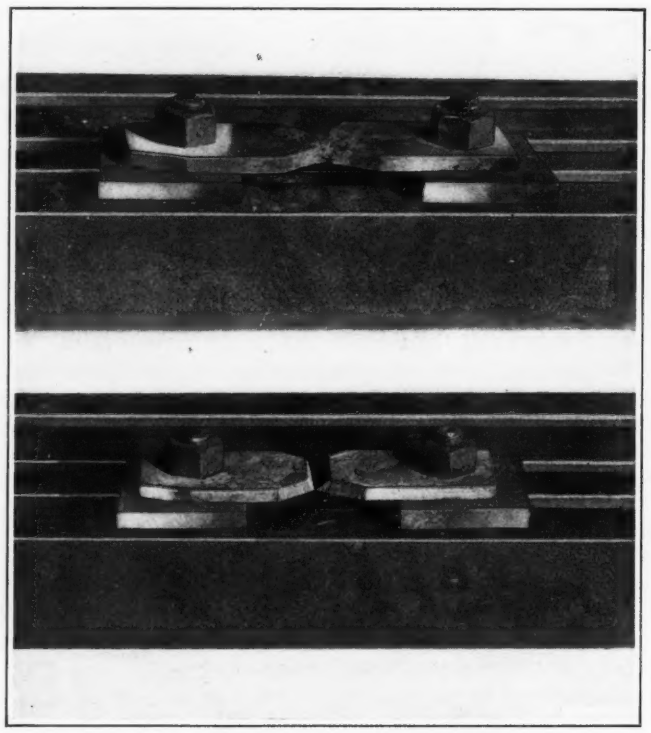


Fig. 2. Illustration of Contraction Stresses

the bottom, and the bottom edges act as a fulcrum. The remedy is to leave the pieces slightly apart, or to clamp or weight them down.

These things occur in every welding job, whether it appears so or not. Holding the ends rigid, compels the expansion from the heat to go to the center, and when the piece cools off, there is sufficient contraction to break it. It is very easy to see what happens in a simple case like the one given, but the successful application of the principle to complicated and unusual cases is a different matter. As a matter of fact, making a sound weld is a comparatively easy thing to learn and many learn it; but the control of expansion and contraction is much more difficult to understand, as it requires a development of the imaginative faculty that is rarely met with, and there are few indeed who master it. It is a specific application of inductive reasoning. The proposition is not, 'if we do not control the expansion and contraction in this piece, it will warp or crack, and be useless", but, "how shall we control the expansion and contraction in this piece so that it will not crack or warp"? In other words, "what cause or combination of causes will produce the result we so much desire"? The practical reply to this question requires experience and imagination, the latter of which enables the welder to successfully apply his experience to an entirely new problem, which could not otherwise be solved, except by cut-and-try methods which are tedious and expensive and generally impossible. In this connection the author advises, when a difficult or unusual piece of work comes in, to sit down quietly and reason out completely the entire method to be followed. Do not decide hastily; time spent in planning is well spent. Control of expansion and contraction will be further discussed in connection with specific cases.

Setting up

In setting up a piece for welding, do it if possible, on a planed surface plate or table, using the finished surfaces of the piece, if any, to go by. If there are none, or if they cannot be used, set up the piece before making the V, using the crack to determine the necessary amount of blocking to hold it in line, and clamping it to be sure that it will not move. Then remove the pieces without disturbing the blocking, V them, replace on the blocking and reclamp. It is well in all

Fig. 3. Hoisting Engine Drum prepared for Welding

cases of complete breakage to separate the parts at the final set-up by just enough to compensate for the shrinkage of the weld. This is absolutely necessary if the original dimensions have to be maintained. The amount of separation varies with the piece and material, but generally 1/32 inch in cast iron and ⅛ inch in aluminum will be sufficient; experience alone will tell. Sometimes the allowance will be incorrect, and the piece will have to be cut and rewelded, changing the allowance. In case great accuracy is needed, tram-marks must be made on the pieces with a very fine pointed tram, so that it will be possible to tell just what is happening. Center-punch marks are of little value, except to keep the tram-marks from being lost, and the tram-marks must be used.

Frequently it is necessary to set up pieces in the fire, either because they are too heavy to weld otherwise, or because of

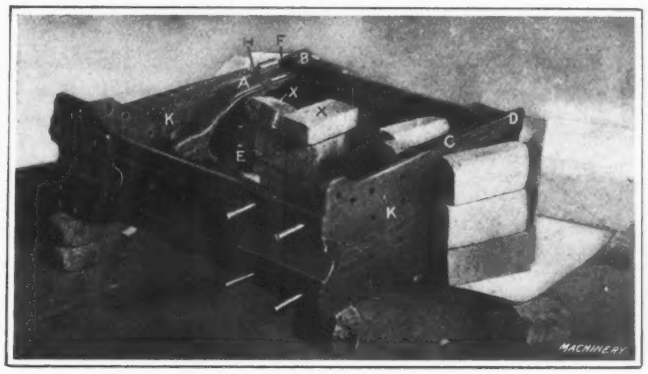


Fig. 4. Example of Preheating

expansion or contraction causing them to break if welded cold. In such cases block them up as if on the table, but be sure that the heat does not affect the blocking or pieces so as to destroy the alignment, which should be again tested before welding; be careful to arrange the blocking to allow this. Sometimes such pieces may be clamped to a heavy block, preferably of cast iron, which does not bend as readily under heat as does steel. The clamps and block should be protected from the fire, or exposed to air to keep them cool, if possible. It is also possible, at times, to take red-hot pieces from the fire and clamp them on the table, or on previously prepared blocking, as the torch will keep the parts hot enough while welding. With heavy pieces in large fires on the floor, it is necessary to be exceedingly careful that the alignment does not change during preheating. The blocking must be of such material (preferably cast iron) and so arranged, that the danger of moving will be reduced to a minimum. The blocking must be on a foundation independent of the fire support, if there is any danger of the latter moving on account of the heat. In any case, allowance must be made for the contraction of the weld, by holding the crack open in some way.

Materials Used for Welding

In almost all cases it is necessary to use additional material to fill up the V left by the preparation of the piece. The material to use for this purpose depends partly on the metal in the piece and partly on the result desired; in almost all cases this additional metal is furnished in the form of wire or rods from 1/16 to ⅜ inch in diameter. Special cases may require larger or smaller sizes, but it has been found that the range given is ample to cover the ordinary run of repair work.

For cast iron the material comes in rods from 3/16 to ⅜ inch in diameter, the small rods being used for small work and small tips, while the heavier rods are for the larger work and heavy tips. When pieces are used up so they are too short to hold comfortably, they may be welded together; but it does not pay at the current prices of this material to weld ¼-inch pieces of cast iron less than 4 inches long, or ⅜-inch pieces less than 3 inches long, as the cost of the gases and labor required is more than the cost of the metal. The cast iron in these rods should be of first-class quality, high in silicon and low in manganese and sulphur, so that it may be easily melted, reducing the gas consumption and consequently the expense, and producing a soft weld. These rods are at present a specialty, and an ordinary foundry cannot produce them. It is a serious mistake to use cheap welding rods of any material, as the gas consumption is much higher and the work much slower, resulting in increased cost.

In welding steel nothing but the best and most suitable wire should be used. Wire purchased at an ordinary hardware store is of no value, as it is hard to melt and will not give good results. It is generally claimed that Norway iron wire is the best for this purpose and that the imported wire

is better than the domestic. The writer is inclined to believe that this is true for ordinary steel, although it does not make a homogeneous weld. A highly polished section through a weld made with Norway iron wire shows a very marked difference between the original and added materials. Etching such a piece for microscopic examinations shows the difference still more clearly, the etching action being much slower on the added material. It is, however, somewhat of a question in the writer's mind as to whether material with a small percentage of carbon, say 0.1 per cent, would not give better results, provided the impurities such as sulphur and phosphorus were kept to as low a point as is the case in Norway iron. The trouble with ordinary iron or steel wire is not so much the carbon percentage, the writer believes, as the impurities present, such as slag, sulphur, phosphorus, etc. There are other matters in connection with this subject that have never been investigated as far as the author knows, and inasmuch as their investigation requires great accuracy, and considerable time and expense, the lack of information is not to be wondered at. It is a fact, however, that the use of Norway iron or any pure iron wire gives good results, and until the matter is more carefully investigated, one is safe in using that material.

There are advertised a number of other materials such as nickel steel, vanadium steel, etc., with which the writer has had no experience. On theoretical grounds, however, the use of these materials is questionable. Vanadium is never added to steel in any appreciable amount. Whether such steel would retain its properties on heating to the welding temperature is still another question, and if a weld can be produced by the use of Norway iron, which is strong and ductile enough, the use of alloy steels appears to be unnecessary. The use of alloy steels for welding has never been investigated, and as in other matters of this kind, innovations should be followed with caution.

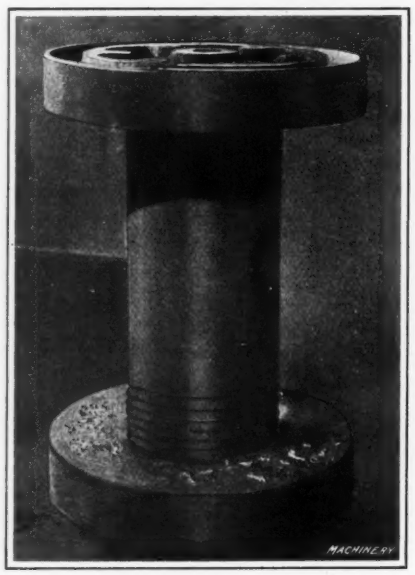


Fig. 5. Same Drum as in Fig. 3, welding completed

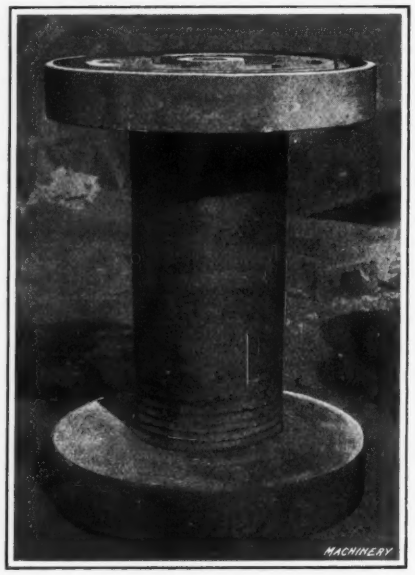


Fig. 6. Drum shown in Fig. 3 finished

For cast aluminum, an alloy of 93 per cent aluminum and 7 per cent copper, which is the standard No. 12 mixture, gives satisfactory results and can be cast by any good aluminum foundry in sticks ¼ inch in diameter and 12 inches long. It is convenient for small work to have sticks 3/16 inch in diameter and sometimes for large work ⅜ inch is better, but it is seldom that either of the two latter sizes is required. For sheet aluminum, strips of the same metal are generally most satisfactory, though aluminum wire will frequently be all right. Cast aluminum sticks cannot be used.

For welding copper, copper wire or rod having a small percentage of phosphorus is necessary. The phosphorus eliminates the oxygen which would otherwise be absorbed by the copper, and which would make the weld porous.

For almost all brasses and bronzes, manganese bronze is most satisfactory. It can be used in the form of ¼-inch sticks 12 inches long and can be made by any good brass foundry. For sheet brass, rolled manganese bronze or tobin bronze rods of the proper size, 3/16 or ¼ inch, are most satisfactory, as they make a little smoother weld and are more fluid. This fluidity is sometimes a disadvantage, particularly in welding on curved surfaces, and it is well to have the various kinds of welding rods on hand, using the one that suits the case best. As far as strength is concerned, there appears to be no practical difference.

In the case of thin sections of malleable iron which are "white-heart" entirely through, it is possible to weld them with regular steel welding wire, and this should be attempted in such cases before anything else is done. In "black-heart" castings, the use of steel wire will simply result in the metal sticking to the wire and pulling away from the casting, the same as when it is attempted to use welding wire on cast iron. In addition to this, blow-holes apparently form in the piece. In cases where strength is not necessary, such as in filling holes or covering over defects, cast iron is the best material to use. It amalgamates quickly with the malleable iron and makes a good smooth job, but the chances are in favor of hard spots being produced, or the melted malleable iron becoming white or chilled iron on solidifying. For the majority of work, manganese bronze is the best to use, and that coming in rolled rods is most satisfactory. Properly used, a first-class job can be done, and as the bronze is stronger than the malleable iron, the weld, if properly made, will give no trouble. Malleable iron should not be brought quite to the melting point, and after a little experience, this can be determined with great accuracy. If it is hotter than this, it is detrimental to the strength of the casting. It should not be forgotten that no two pieces of malleable iron are alike and that it is impossible to predict what the result will be before the welding is begun.

It is sometimes advisable or necessary to weld broken leaves in automobile springs, and while it appears a doubtful performance as far as strength is concerned, the writer has never known one welded in his shops to break. The proper material to use for this is old bed springs, which can usually be found around an ordinary scrap yard. Ordinary welding wire is not satisfactory. Care must be taken in using this material not to burn it. A fairly large tip should be employed and the work done rapidly.

The welding of cast steel is generally possible and gives good results. There are some kinds, however, that are difficult to weld, and others can only be welded with cast iron. Evidently, if strength is a consideration, cast iron must not be used. Usually ordinary welding wire is suitable, but it is well to keep the pieces that are cut out during the preparation, so that in case it is found difficult to weld with ordinary steel, the pieces themselves may be used as a filler, at least as far as they will go. Sometimes it is possible to cut off surplus metal from other parts of the casting and use it.

The welding of tool steel is generally unsatisfactory, particularly where the material is to be used for heavy cutting. It is not possible to avoid entirely the burning of the metal. Borax or other suitable flux should be used as a coating for the steel, to keep the air from it. The use of spring steel wire for filling, and of a rather large tip, with the quickest possible speed for doing the work, will give as good results as can be obtained. It is a material that is very seldom handled in repair shops.

Preheating

In order to make a fusion weld, the metal in the pieces to be welded must be brought to the melting point; and as all metals are good heat conductors, the pieces will be heated for some distance from the weld, the temperature of the piece decreasing as the distance from the weld increases. All of this heat must be supplied in some way, and it is possible

to do it with the welding torch in case the section is light. The matter is different for heavy sections; for, while the intensity of temperature of the welding flame is very high, the quantity of heat in it is very small; also, the cost of the welding gases is high, so that some other fuel is more economical where much heat has to be provided.

Many pieces must be kept hot all over while being welded, and this cannot be done with the torch. Such parts as water-jacketed cylinders, cast-iron heating boiler sections, aluminum and cast-iron crank-cases and transmission cases for automobiles, and other large castings come under this head. Good hardwood charcoal is then the best all-around fuel. It burns without smoke, does not injure finished surfaces as does coal, gives off no offensive odors, burns slowly and evenly, does not need a fan blast to keep it going, will heat any piece red-hot, and is easily controlled. Many pieces have to be cooled off in the fire so that they will not contract too fast or unevenly. Charcoal is also the best fuel for this purpose, as the heat from it dies out slowly.

The best hardwood charcoal is necessary. That made from soft wood breaks up easily, has little heat, and clogs up the fire so that it does not burn well. It is advisable to remove the dust and small pieces, by screening through a ½-inch mesh sieve. For handling charcoal from the storage bin to the fire, old carbide cans with the top cut out, are very convenient, and save many steps. It is well to store as little charcoal as possible, as it is easily ignited by a chance spark; and as it gives no warning by smoke, it is liable, if ignited, to gain considerable headway before being observed.

Gas furnaces are very convenient for preheating to reduce the torch gas expense, but for anything else they are of little value. Kerosene torches are frequently of value for heavy work of certain kinds, especially where no contraction strains exist. Gasoline torches cannot be recommended in a welding shop. In some cases ordinary Bunsen burners or modifications similar to those used in gas stoves may be used, particularly on light work. They are of special value where many pieces of one kind have to be welded, because the burner can be made to suit the job.

A very satisfactory method of preheating shafts and other solid pieces is by the use of a gas torch using illuminating or natural gas and compressed air under about one pound pressure. These torches may be held in clamps, and mounted on a flat firebrick-covered table, which may be surrounded with firebrick, to keep in the heat. It is necessary to have a blower to obtain the air pressure, and its operation is somewhat costly, unless there is plenty of work of this kind, which is not often the case in a repair shop.

There are two objects for which preheating is used. The first, merely to heat the piece to save time and gas and make a better weld; and the other, to take care of the natural contraction of a welded piece. In the first case, which applies to plain heavy pieces, it is only necessary to put them in the fire, heat them as rapidly as possible, weld them, and let them cool off slowly. The second case is very different. Such pieces as gas engine cylinders (which have two walls joined together to form a water space), flywheels with heavy rims and light spokes, stamping press and punch press frames with two rigid uprights, automobile crank-cases of aluminum or cast iron, or any other pieces where the shrinkage of the weld would produce a strain, should be preheated in part or as a whole so that the strains during the cooling may be equalized or eliminated. It is impossible to give any general directions, but specific cases are treated of later.

The only guide at the present time as to the amount to which a piece should be preheated is experience. It may be said, however, that as far as eliminating strains or securing a sound weld is concerned, taking nothing else into consideration, the hotter the piece is heated the better. Care should be taken, however, not to heat a piece so that it will distort. It is easily possible to heat a cast-iron piece so hot that if not properly supported it will sag at the unsupported place, and, of course, care must be taken to avoid this. This property of cast iron is, however, of value at times in straightening pieces that have been warped by welding, it being possible in many cases to clamp a piece at one end rigidly on a true surface and pull the other end down slowly with another clamp, while keeping the weld quite close to the melting point with the torch.

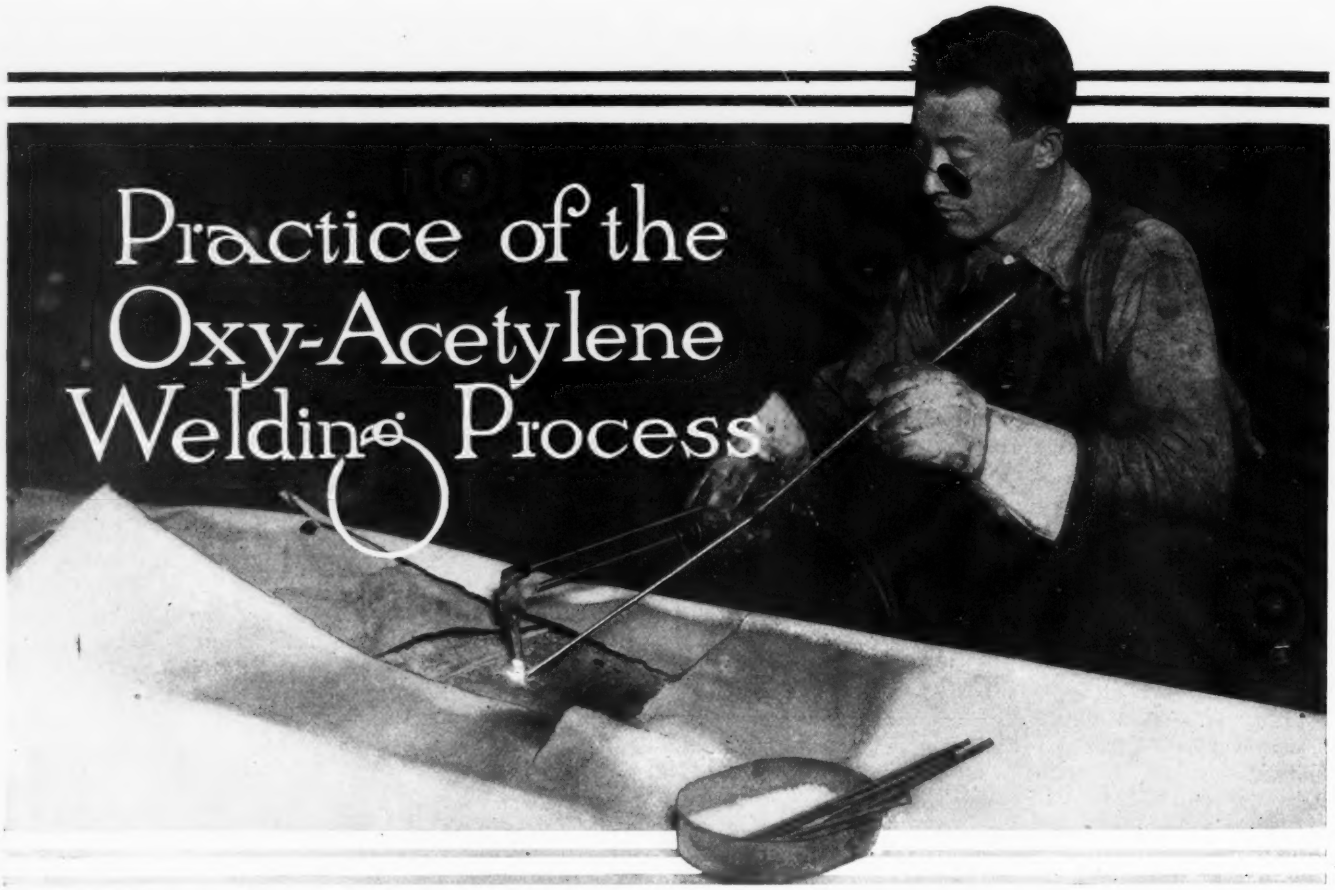
Examples of Preheating

In Fig. 4 is shown an instance of the necessity of proper preheating to insure sufficient expansion so that there will be no strain in the piece after welding. The two sides *K* are identical in construction and the section below the piece broken out is identical with it. The casting is about 3½ feet square, and the thickness of the welds, except at the flange, is about 1¼ inch. In order to check the expansion, tram-marks were made at *A*, *B*, *C* and *D*, *AB* being equal to *CD*. Inasmuch as the casting was very rigid, it was necessary to take special precautions to avoid strains in the welded piece. The method followed was to heat the side *CD* both top and bottom to a sufficient temperature to give an equal expansion to that of the side *AB* which was heated only at the bottom, in order to keep the top as cool as possible, forcing the expansion to take place everywhere except at the break, the torch being sufficient to counteract the heat at the part below the break. The fires were started slowly, charcoal being used. The fire on the side *CD* is longer than the one at *AB*, the latter being very little longer than the piece broken out, but care was taken to tram both sides just before welding to be sure that the expansion was the same. During the firing, side *CD* was kept covered with asbestos paper, while the piece broken out and the casting in the vicinity were not so covered. Care was taken, however, to prevent sparks from rising from the fire by covering the space between the bricks and *AB*. The illustration shows the bricks *X* laid on their side to permit a good view of the breaks, but they were later placed on edge in order to confine the heat. The fire, however, was not allowed to reach the break, but was kept about 3 inches above the bottom section. A large tip was used to make the welds, as the casting was comparatively cold. Weld *F* was made first, allowed to cool to the temperature of the casting, the tram-marks checked again, and then weld *H* made. Both welds were burnt entirely through from the top, and each one was finished underneath after it was made, taking down enough of the outside bricks to reach it, and covering over the fire to hold the heat in the bottom section. After welding, this cover was removed, the bricks replaced and the casting allowed to cool down in the fire. It was found that before welding at *H*. the crack was open about 1/32 inch, which was sufficient under the conditions to take care of the contraction. It is necessary in this and similar cases to make the weld as quickly as possible, so that the heat conditions at all points will remain as nearly constant as possible.

Fig. 3 shows the method of preparing, blocking up and preheating the rope drum from a hoisting engine. Both ends were cracked in the same way, although the upper one in the illustration was not cracked so badly. It was impossible to prepare the drum from the other side, which would have been desirable on account of the greater ease of doing the work, as it could have been done under a drill press. The crack extended through at the root of the friction block cavity, making it impossible to prepare by any other method except that used. An electric drill was used and the necessary material chipped away as shown, the same procedure being followed on both ends to produce the V's. As the casting was quite heavy, it was necessary to block it up inside of the crack, because if it had been blocked up under the outside, it would probably have been distorted when it became red-hot.

Fig. 3 also shows the pieces of sheet iron practically surrounding the casting, and the charcoal in place ready to ignite. Of course, pieces of sheet iron entirely surrounded the flange during the preheating, welding and cooling off. Care was taken to melt through the bottom of the crack to insure a sound weld. Fig. 5 shows the piece after welding. There was no necessity for any finishing except just sufficient grinding with a flexible shaft emery wheel to remove the principal roughness, so that the rope would not chafe.

Practice of the Oxy-Acetylene Welding Process



THERE are a number of points to be considered in a general way in oxy-acetylene welding, which apply equally to the welding of all metals. These will now be considered, and in subsequent articles the special points applying individually to each metal will receive attention. Some of the instructions may seem unnecessarily minute, and even superfluous. In some cases full explanation cannot be given without going into metallurgical theories more than is thought wise, but the reader may rest assured that for what is said there are good reasons, and the author has obtained the best results by adhering closely to the rules laid down.

General Rules

1. Follow strictly and without deviation the instructions given by the manufacturers of the apparatus used, in every respect. Reputable manufacturers, the only ones whose apparatus should be purchased, are not only willing, but anxious, to assist when difficulties are encountered. These manufacturers have spent thousands of dollars to find out how to handle their apparatus, and it is to be assumed that they know the best way and instruct accordingly.

2. Remember that a welding torch is an instrument of precision, and handle it as such. Throwing it down on a table, dropping it on the floor, or other misuse, is sure to result in more or less injury to the welds made. If the torch tip becomes hot, do not plunge the whole head in water. Cool off the tip first. When it is thoroughly cool, the head may be cooled off. Lack of attention to this point in certain types of torches will damage the end of the tip in the head, and may cause injury to the threads in the head, when the tip is removed.

3. Keep all the torches in first-class condition, free from leaks, and with clean tips. See that the gages register properly at all times, and that the reducing valves act promptly. Good results cannot be obtained with defective apparatus. See that all joints are tight, so that neither acetylene nor oxygen may be wasted. An oxygen leak may not seem very dangerous, but it may result in a rapid burning of the welder's clothes or cause some wooden article to burn where a spark falls on it, when otherwise no damage would result. An acetylene leak is dangerous. If it were generally appreciated that a quart can filled with an explosive mixture of acetylene and air has enough potential energy to kill a person nearby, no acetylene leaks would be permitted. Be particularly careful to see that no leaks exist in the hose or torch. The hose on the floor is liable to have pieces of metal dropped on it which damage it, and even with the best of care it will in the course of time wear out, the inner lining becoming porous and allowing the escape of the gases. Hose in this condition cannot be repaired; it is dangerous and should be replaced at once. Leaks around the torch are liable to burn the welder and cause explosions, and should not be tolerated.

4. Adhere strictly to the pressures specified by the manufacturer for the different sizes of tips. Do not attempt to force the tip by increasing the gas pressure to obtain a larger flame, but use a larger size of tip. The excess of oxygen caused by the forcing of the tip will result in decreasing the strength of steel welds and will damage other welds seriously. This is a point which is generally overlooked, but which is exceedingly important. Use a tip large enough to do the work easily, but under no circumstances use too large a one, as damage to the weld will probably result.

5. Unless otherwise specified, always use a neutral flame. The flame of a torch may contain an excess of acetylene or an excess of oxygen, or it may be strictly neutral. It is not to be understood by the expression "neutral" that one torch may not consume more oxygen than another even when the flames appear neutral in both cases. The neutrality of the flame refers to the small welding flame only, and simply indicates that to the eye the flame has just sufficient oxygen to burn the acetylene completely and no more. If care is not used a considerable amount of oxygen, over and above this requirement, may escape through the torch tip and damage the weld.

Fig. 1 shows a photograph of the neutral flame as it appears to the eye, but magnified three times. The length is about three times the diameter of the largest part; the small, intensely white flame *A* is sharp in outline, and is symmetrical and smooth. A jagged or irregular flame indicates that the hole in the end of the tip is not true, or is rough; it is necessary occasionally to run a drill of the

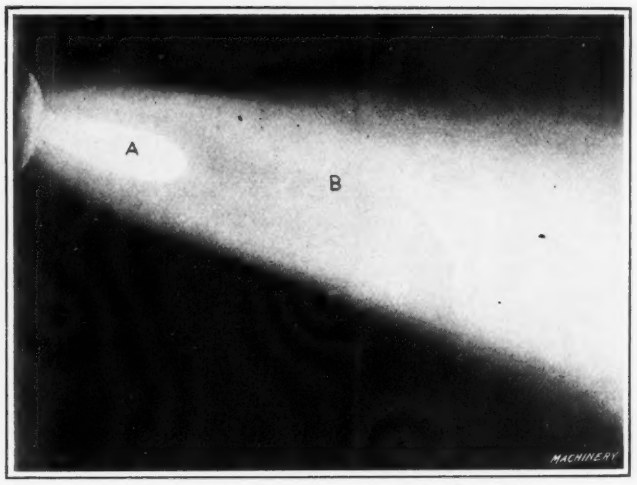


Fig. 1. Neutral Flame enlarged about Three Times

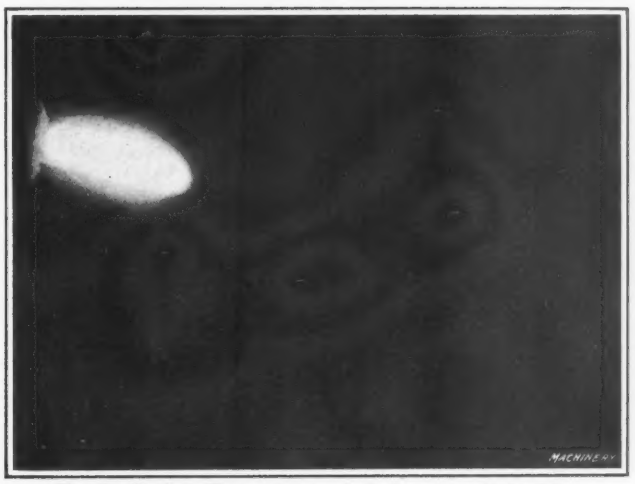


Fig. 2. Neutral Flame photographed through a Light Filter

proper size carefully into this end and to clean it out and true it up. The thinner flame *B*, as it appears in the illustration, is due to the burning of the hydrogen left when the acetylene is broken up into its constituents, carbon and hydrogen. The fact that the photograph was given a one-minute exposure with a very rapid plate shows that the conditions were not very different during that time, because of the sharp outlines of both flames. It might be stated that this stability of the flame is characteristic of the torch used to produce the photograph.

Fig. 2 shows the correct shape of the neutral flame. This photograph was taken with quite a long exposure through a light filter, the conditions not being changed in any way from those under which Fig. 1 was taken. It will be noticed that, while the flame is of the same length, the width has been reduced; the hydrogen flame has practically disappeared. It will be also noticed that there is a considerable halo on both sides of the flame, which the writer believes is caused by a small amount of acetylene which escapes without combining directly with the oxygen, and which is probably burnt by oxygen from the surrounding air. It will be noticed that there is none of this halo at the end of the flame. This, however, does not appear to be of serious importance from the practical side of welding.

In Fig. 3 it will be noticed that the neutral flame has entirely disappeared and in its place is a longer white flame, characteristic of an excess of acetylene. When the acetylene is reduced, or the oxygen increased, this flame decreases in size and becomes sharply defined. Upon a further increase of oxygen with no change in the acetylene this sharply defined neutral flame becomes somewhat shorter and takes on a violet tint which indicates a surplus of oxygen in the flame itself. If the increase of oxygen continues, the flame will be blown out. This excess of oxygen flame is shown in Fig. 4, and it will be noticed that it is shorter than the neutral flame and also smaller in diameter, and that it has a bulbous enlargement at the end, while the neutral flame, as it appears to the eye, is more elliptical. It will also be noticed that the outline of this flame is sharper. The hydrogen flame has a peculiar shape at the top. The cause of this is not at present known, but it is probably due to the peculiar shape of the small flame, which is not symmetrical. It is believed that this is the first time that micro-photographs of the various flames have been published, and their appearance indicates the necessity of further study of them. For the present purpose, it is enough to show them as they actually appear.

6. Always light the acetylene first and turn it off last. In some types of torches this may avoid an explosion or "back-fire," which, while it may cause no damage, is to be avoided whenever possible. Back-fire, as it is commonly called, is really a burning of the acetylene inside of the torch. This, of course, is accompanied by a deposit of soot which may collect in the small passages and prevent the torch from working satisfactorily. If this is the case, the passages will have to be cleaned out, although sometimes the deposit will burn out after a short period of use. The temporary reduction in the size of the welding flame, however, tends to make a bad mixture, with resulting damage to the weld. Never use any oil or grease around a torch, or for that matter, around anything exposed to the action of oxygen. Fires may result from this, as the oil is rapidly oxidized with a considerable increase of temperature.

7. It may seem superfluous to call attention to the fact that an acetylene leak, particularly in a generator, should not be stopped by attempting to weld it, or by using any heat at all; but the writer knows of one case of this kind which resulted in the explosion of the generator and the instant death of the man who attempted to weld it.

8. In case repairs are needed on the torch, it is best to send it to the manufacturers. Of course, a mechanic familiar with the construction can make repairs, but the relation of the sizes of the passages to each other must be maintained for efficient work, and the manufacturer can do this best.

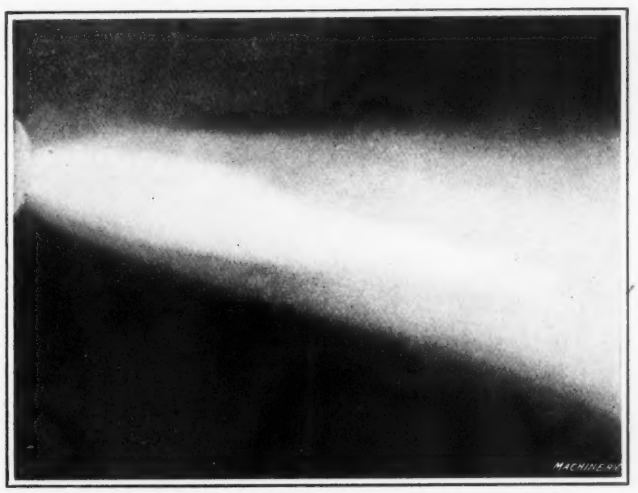


Fig. 3. Appearance of Flame with an Excess of Acetylene

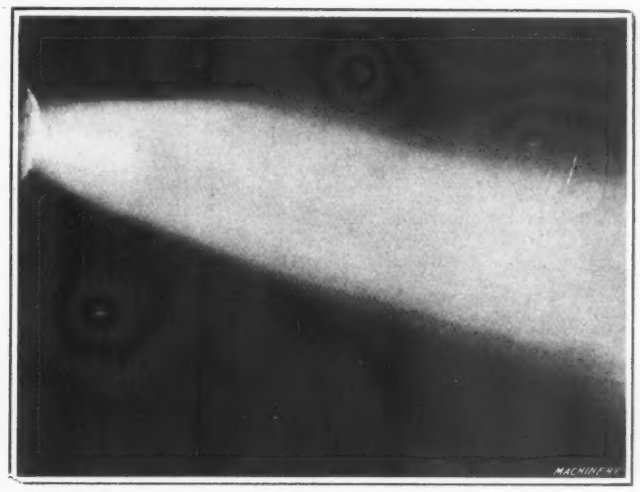


Fig. 4. Appearance of Flame with an Excess of Oxygen

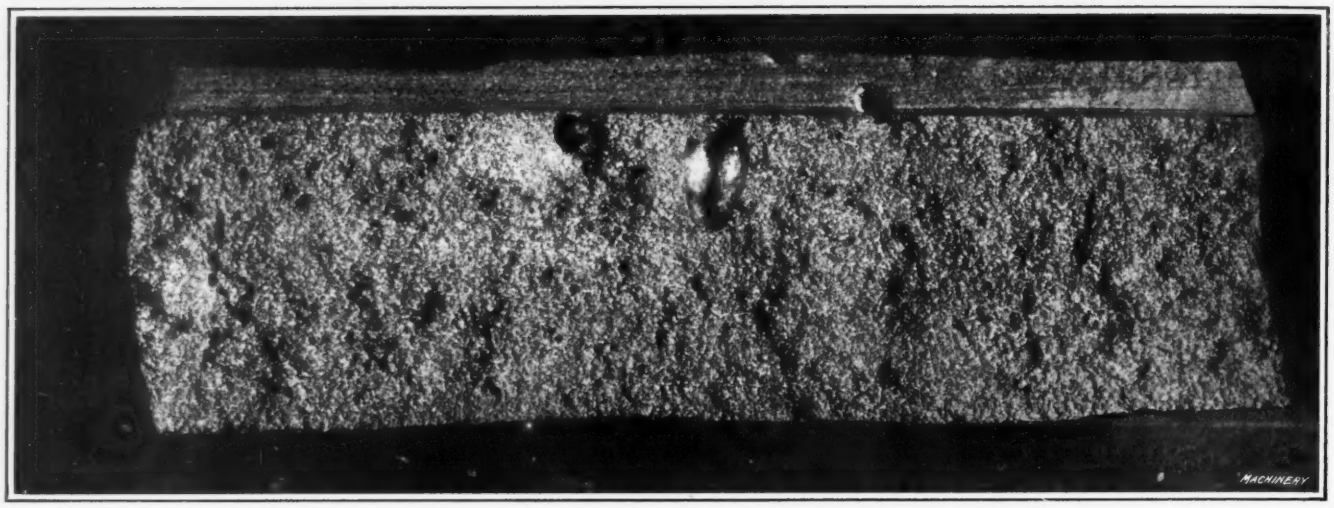


Fig. 5. Section of Cast-iron Weld broken at Right Angles to the Line of Weld and magnified about Three Times. Note Uniformity in Grain of Iron

9. Never use copper tubing for acetylene piping. It is easily attacked by acetylene, particularly if it is impure, and an explosive compound is created which detonates at the least shock.

Welding Cast Iron

Cast iron is the easiest metal to weld and therefore should be the first one tried by the beginner. It is best to begin with small pieces, say $\frac{3}{8}$ by 2 inches in section. Bevel both sides of the two pieces so that the included angle is about 90 degrees (see Fig. 1 in the preceding article) and grind off the sand, scale and dirt for about $\frac{1}{2}$ inch away from the V. Set the ends about 1/32 inch apart, and somewhat above the surface of the table, say on two V-blocks of the same thickness. Use the size of tip recommended by the manufacturer, adjust the flame to neutral and bring both edges to a bright red; then melt down the bottom of the V, applying a little flux or scaling powder with the heated end of the filling rod. Do not add any metal from the filling rod until the bottom of the V is filled from the sides. Be sure that the metal runs together freely. When ready to add metal, put the end of the filling rod in the melted metal of the weld and play the flame on both the rod and the weld so that the metal runs together. As often as is necessary dip the rod in the scaling powder and proceed with the filling in. Be careful not to add too much at one time, using just enough to make the metal run freely. The weld should be made in steps. If too much metal is added in one place, it is likely to run over into the bottom of the V, and unless the welder is experienced and careful, will cause a cold shut which, of course, makes a defective weld. As the filling progresses, be sure that the metal is welded at both sides. Most welders are right-handed and the tendency is to get the left side of the weld well made, while the right side is likely to be "cold-shut" on account of sufficient heat not being applied at that point. The "feel" of the torch in the hand turns the tip toward the left rather than the right. Left-handed welders, therefore, will do just the reverse.

After all the metal necessary has been added (it should be enough to raise the weld slightly above the surrounding surface), play the torch flame at the junction of the old and new metal until the new metal runs into the old. At this time, do not add any scaling powder. If this is done properly, and it should, in fact, be done at intervals, as the weld progresses, there will be no hard spots at the junction. These hard spots are caused by the melted metal striking a colder surface and chilling. They may be caused, even with the utmost care on the part of the welder, by unsatisfactory welding material, but with good material and care they will not exist. The scaling powder has nothing to do with them, but does at times, if of certain compositions, produce a thin intensely hard scale, which, however, is readily removed by chipping or grinding.

It should be remembered that the beginning and end of a weld require less heat than the middle, because there is not the amount of metal present to absorb the heat, and unless care is taken to keep the torch somewhat away from the metal at the beginning and end, the tendency will be to burn it; also, at these points, in the case of cast iron, there is a tendency for the metal to run away, and when adding metal there, the torch flame should be directed toward the center of the piece rather than toward the edge. It will also be found best to use but little scaling powder, as the slag which forms on the surface of the iron tends to hold the melted metal in place. In many cases the welding rod can be held close to the edge, and by manipulating it and the torch the metal will be held in place.

After one side is welded, turn the work over and repeat the operation on the other side, beginning where the weld on the first side ended; this saves gas. After the sides are welded, it is advisable to touch up the edges so that the metal will be welded entirely through the V's. Enough metal should be added so that the piece will "square up" when ground to its original size, and care should be taken that it does not run away. Evidently the full heat of the torch is not

Fig. 6. Weld in Cast Iron beveled from One Side. Top of Weld

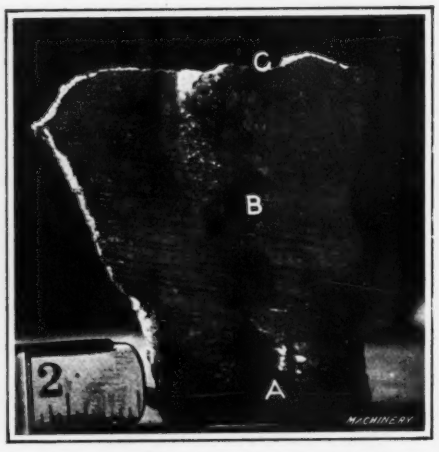


Fig. 7. Weld in Cast Iron beveled from One Side. Bottom of Weld

Fig. 8. Weld in Cast Iron beveled from One Side, but Broken, showing Defects

needed at these points. In the case of a small weld like the one described, there will probably be no casting strains. It is wise, however, to take the precaution of heating the weld uniformly in order to be sure that this difficulty does not exist. After the weld is finished, allow it to cool off in a dry, warm place. When cold, grind or otherwise remove the surplus metal to the same size as the original casting, and put it in a vise with the top of the jaws at the center of the weld. If the weld has been properly made, it will be found impossible to break the piece with a hammer, except outside of the weld. It should be necessary to break off the piece at both ends of the weld and then break the weld crosswise (or lengthwise of the original piece) to see what the fracture looks like. If this is done, it will be noticed that the weld merges into the original metal without any distinct line of demarkation, and that the grain of the weld is somewhat finer than that of the casting; also that the color is slightly different, being generally a trifle darker. The finer grain is due to the fact that the metal is added in small quantities, and therefore cools more quickly than the whole casting does, which produces a finer grain. In a properly made weld, the V should be much larger than the one made in the preparation before welding, because of the melting down of the sides. The difference in color is due to the difference in quality between the filling rod and the casting.

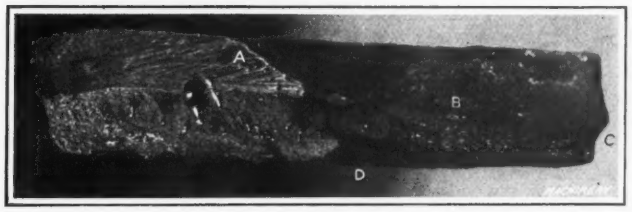


Fig. 9. One of the Pieces in Fig. 8 shown about Three Times Natural Size

Fig. 5 shows the uniformity of structure of a properly made cast-iron weld. There is a slight difference in the size of the grains between the center where the weld is, and the body of the casting, the latter being somewhat larger. This difference is more noticeable in a larger piece, and is more apparent in the piece itself than in the illustration.

There is a small projection just to the left of the center of the large blow-hole, which is a particle of foreign matter, probably sand, that gave off enough gas to produce a blow-hole. This can be eliminated in welding by melting to the bottom of the hole and floating the dirt to the surface.

The first piece welded by a beginner will probably show defects caused by the metal not being thoroughly melted and only sticking together in some places instead of being solid. The only way to gain experience is to break a considerable number of pieces and repeat the trials until a sound weld is easily made. The difficulty in making sound welds increases with the size of the piece, and until one is sure that he can make good welds in small pieces, he should not try large ones. It may also be found that the proper size of tip is not used. Too small a tip will result in cold shuts and slow work. Too large a tip will result in blowing the metal away on account of the higher oxygen pressure used, which also makes the work slow, and tends to burn out the carbon of the iron, making it hard and brittle. The proper size of tip can be found after a few trials, and experience will soon tell a welder what tip to use without trial.

As an illustration of the defects that are likely to occur in a cast-iron weld, the piece shown in Figs. 6 to 9 was prepared—the beveling being done from one side only, and the piece nicked with a hacksaw and broken in order to show the defects more clearly. Fig. 6 shows the front of the weld or the top as the work was being done, and shows how the weld should be made in steps in order to prevent cold shuts. The steps extend from *A* to *B*, the portion from *B* to *C* being welded entirely through, some of the metal hanging from the bottom of the weld in drops. Fig. 7 shows the back of the weld, and it will be noticed that from *A* to *B* the original break remains, while from *B* to *C* it has disappeared. In this view it would appear that the weld is very nearly through, but upon examining Fig. 8 it will be found that it is not through by about ⅛ inch, due to the bridging action of the melted metal heretofore referred to. This is the real danger of a weld that is not burnt through. It is apparently sound, but really the condition is much worse than it appears. It will be seen, however, that where the metal has been burnt through, the weld is perfectly sound. As a matter of fact, it was found impossible to break the weld without nicking it with a hacksaw. At *C*, Figs. 8 and 9, will be seen a spot where the metal has run over from the added material, forming a cold shut, which is very distinct, and, of course, a serious source of weakness. In addition to the above, it will seen that the weld is full of blow-holes for some distance from the bottom of the V. These were caused by adding metal before the pieces were thoroughly hot. The part of the weld which is level with the original pieces seems to be sound at the top, which is proof that while a weld may be sound to all appearances, it may be very far from sound inside.

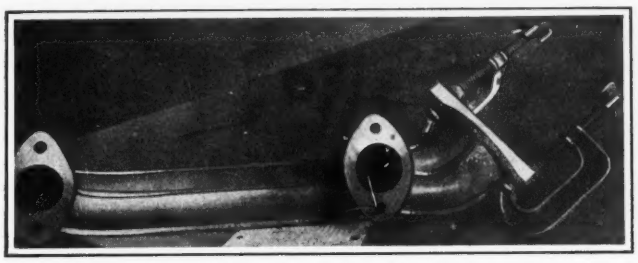


Fig. 10. Cast-iron Manifold on which Broken Lug is to be welded

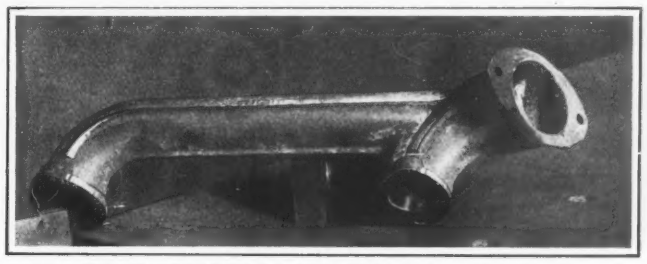


Fig. 11. Completed Weld of Manifold shown in Fig. 10

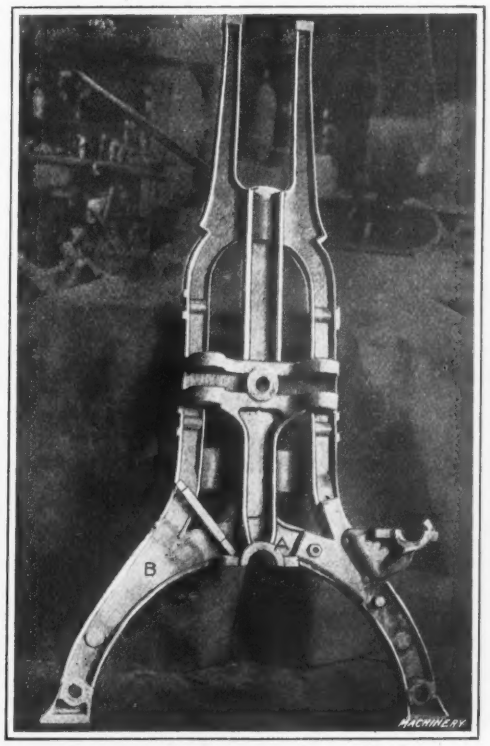


Fig. 12. Machine Frame with Babbitted Bearing close to Weld

Examples of Cast-iron Welds

Fig. 10 shows a cast-iron exhaust manifold with one of the bolting lugs broken off. This is quite a frequent occurrence, and is generally due to the sharp corner left when the nut-side of the lug is machined. In order to keep the broken lug straight with the rest of the face, a planed piece of cast iron is clamped across the face, as shown. It is best to weld the back of the lug first on both sides of the clamp, going almost through. Then the clamps and block can be removed and the job finished.

It is easier in many cases to hold such pieces in a vise than to block them up on the table. After the weld is made on the outside, the inside

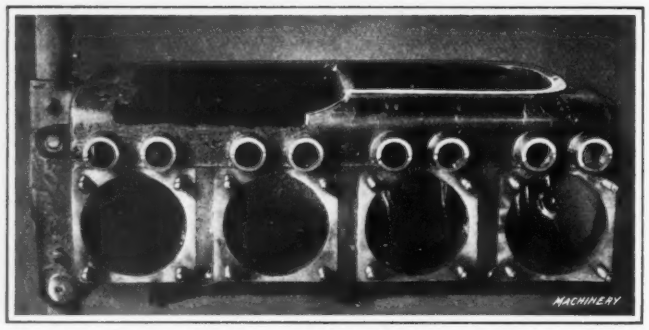


Fig. 13. Cast-iron Crank-case in which Broken-out Piece is Missing

should be finished, care being taken to burn out all remnants of the crack. The last thing done should be the finishing of the faces, and care should be taken to avoid hard spots. If it should so happen that the lug does not come true after the weld is finished (it should be tested with a straightedge), a small amount of metal can be added so that there is sufficient stock to grind and file. The finished weld is shown in Fig. 11.

Fig. 12 shows the frame of a machine in which the break *B* occurred close to a babbitt bearing *A*. It was decided to save this bearing if possible, as there would have been con-

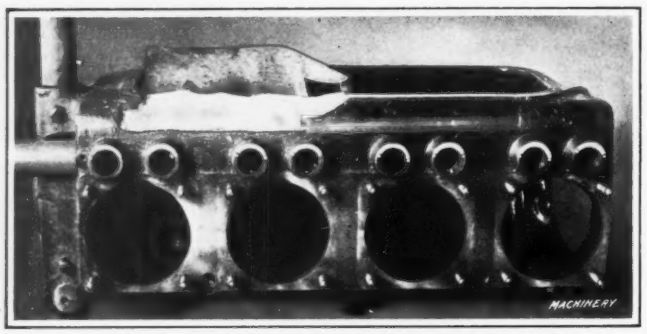


Fig. 14. Asbestos Backing for Plaster-of-Paris Pattern in Place in Casting shown in Fig. 13

siderable expense in renewing it, not so much on account of the babbitt, as because of the difficulty of alignment. No finishing was necessary at the weld. This made it much easier to save the babbitt, because even if a few hard spots did exist at the weld, it would make no difference. The casting was laid flat on the table, the parts lined up after preparation, and preheated with a Bunsen burner, during which time wet crushed asbestos was kept on both the top and bottom of the babbitt bearing. At frequent intervals water was poured on the asbestos to keep it wet. As soon as the casting had been well warmed, the weld was made on one side, using a heavy tip, which was necessary on account of the absorption of heat by the cool metal. After the first side was finished, the work was turned over, repacked in asbestos, and the weld completed. The weld was then heated uniformly its entire length with the torch and allowed to cool in the air. Had the break occurred at about the place where the rule is shown, it would have been impossible to save the babbitted bearing, and an entirely different procedure

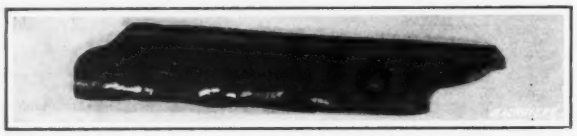


Fig. 15. Casting that is to be inserted in Place of Broken-out Piece in Fig. 13

would have had to be followed. Undoubtedly the babbitt would have been melted out and more care would have had to be taken to prevent the contraction of the weld. Two torches would have been advisable, welding both breaks at the same time.

Welding a Cast-iron Crank-case

Figs. 13 to 17 show a large cast-iron crank-case of the barrel type, with a piece broken out and missing. Fig. 13 shows the preparation of the edges, which was done prior to making the pattern for the missing piece. This is permissible in this instance, because the metal is cast iron and somewhat over ¼ inch in thickness, and also because the new casting used in repairing was made with enough stock on it to allow for finishing on the hand-hole face. Fig. 14 shows the asbestos backing for the pattern, supported by a sheet of iron and a mandrel through the cam-shaft bearing holes, this being an easy way of supporting the backing in this case. Broken up asbestos paper is now used altogether in the author's shops for the purpose indicated, on account of the ease and rapidity with which it can be applied. Prior to its adoption, it was the custom to use plaster-of-paris, trimming it off to the inside surface of the pattern it was desired to make. The asbestos used is soaked in water and squeezed out until it is just plastic. It is then pressed into place and smoothed down uniformly to the desired level. A sheet of tissue paper is then placed on it and oiled to prevent the plaster-of-paris used for the pattern from sticking to it. The plaster-of-paris is next poured into place, and as it gradually hardens, it is brought to the required contour and allowed to dry. The result is shown in Fig. 16, in which it will be noted that sufficient stock for finishing has been left on the hand-hole face of the casting, and that the plaster-of-paris, when dry, has been beveled out to make the V. A gentle tapping on the casting around the pattern loosens it, and it is easy to lift it out without breakage. Care should be exercised at this stage of the operation, and the plaster-of-paris should be allowed to become quite hard, although it need not be entirely dry. Upon removal, air-holes and irregularities on the inside face will be found, and they should be filled up. Attention should also be paid to so making the pattern that it can be drawn from the sand.

The casting made from this pattern is shown in Fig. 15, and the welded job in Fig. 17. This job was welded in a large forge, the break being turned downward into a charcoal fire, allowed to get nearly red-hot, turned over, carefully covered with asbestos paper and welded, but only from the outside, as it was not necessary from the standpoint of strength to do more than this. The weld, of course, was

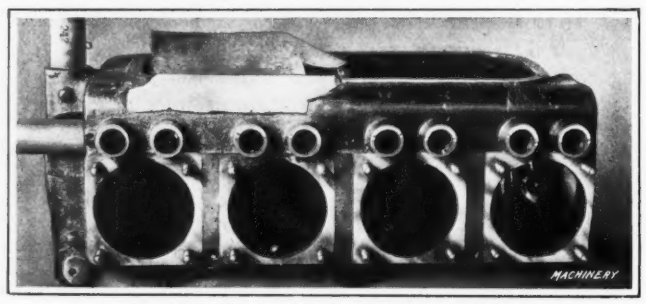


Fig. 16. Plaster-of-Paris Pattern Completed

made entirely through the section, and what beads resulted were chipped off after the case was cold. After welding, the weld was turned into the fire again, allowed to come to a uniform temperature, and then packed in asbestos to cool. In this instance it was not necessary to heat the entire casting to the same high temperature, but the casting was all hot, the coolest part being at a temperature much above that of boiling water. It is one of the instances where it is not necessary to heat the whole casting to as high a temperature as the part to be welded, nor indeed is it desirable to do so. The case is stiff enough to gradually force the contraction to take place in the weld as it is made, and by allowing it to come to a uniform high temperature after

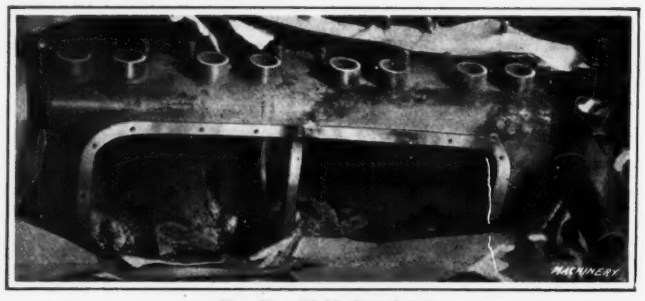


Fig. 17. Weld Completed

the weld is finished, any strains that may be caused in welding are eliminated.

Welding a Shaper Rocker Arm

Fig. 18 shows a cast-iron arm from a shaper. An attempt was made to weld this by some one without either the necessary knowledge or facilities, with unsatisfactory results. The weld at *A* and the opening at *B* showed that the weld did not extend in more than ½ inch. The work was not preheated or prepared. The photograph was taken after the break at *C* was partly prepared at the writer's shop. The essential thing in this piece was to make the edges of the slots *D*, which form a fork at the end of the casting, come at right angles to the surfaces *E* and *F*, and also to have these two surfaces in line. It was necessary also to be sure that the surfaces *H* and *I* were parallel, as a sliding block operates between them. The method of doing this was to clamp the piece on the corner of the welding table, as shown in Fig. 19. In order to remove the chill from the casting to some extent, a Bunsen burner as shown at *A* was directed against the break at *B*. The upper half of the weld was made, the casting turned over and blocked up carefully and the weld finished. It was then tested to see that everything was straight and square. It was found to be in good shape, but if it had not been, the difficulty would have been corrected by heating the weld *B* with a large torch, when the piece *C* could be carefully pulled into position by means of wedges and clamps. The weld was allowed to cool and the piece blocked up on the table as shown in Fig. 20, all the surfaces on the lower side being laid on V-blocks of the same height. The fork-end was then clamped into position so that the slots were true with a square both ways and the top half of the weld *E* made. It should be noticed that there was enough of the finished surfaces underneath *B* and *C* to allow a narrow V-block to be set underneath which held it true in one plane, while blocking was put under the fork to hold it true in the other direction. Of course, the piece was clamped down to the table, while the first part of weld *E* was being made.

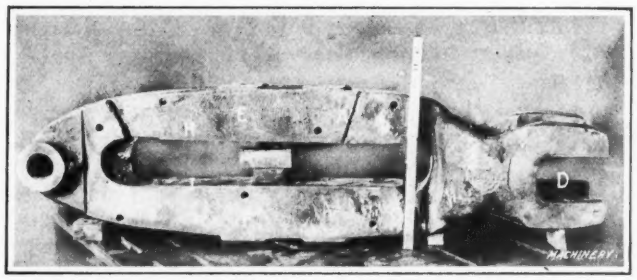


Fig. 18. Shaper Rocker-arm broken in Three Places. This Arm has been improperly welded and is broken again

It was then turned over and the weld finished, and the piece again tested to see that it was in good condition. It is evident that after these operations the piece was true and in line, and with reasonable care would remain so. There was, however, danger of a strain in making the last weld. This was overcome by putting tram-marks at *A* and *B*, Fig. 21, and heating the opposite side in a charcoal fire sufficiently to give the necessary expansion, which was, of course, checked by the tram-marks. The piece was carefully blocked up to be sure that no sagging would take place and half the weld made. It was then turned over and the weld finished, the piece

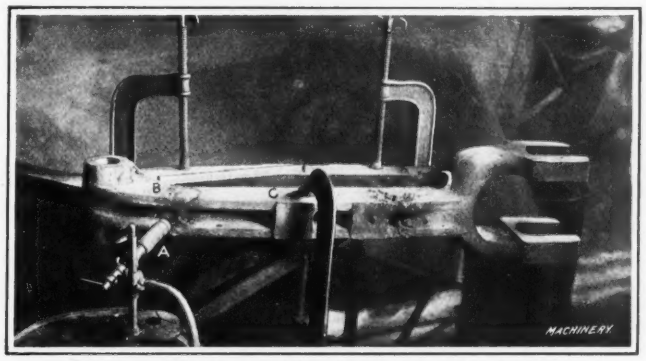


Fig. 19. Method of Holding Rocker-arm while Welding

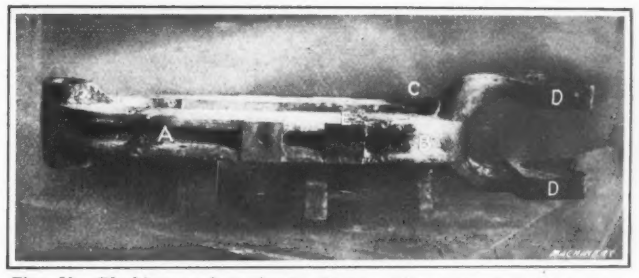


Fig. 20. Blocking used to insure Proper Alignment of Welded Parts while making Final Weld

removed from the fire and allowed to cool down in asbestos. The conditions required that all of these welds be made without heating the piece red-hot, because it would have been very difficult to keep the parts in line, had the whole piece been put in a hot fire.

One difficulty in this case was that all of the faces were more or less worn, and some judgment had to be used in checking them up. However, the piece after finishing gave entire

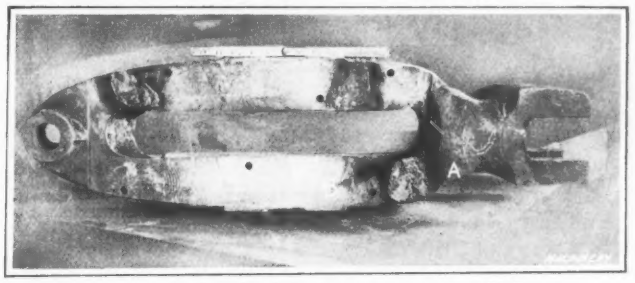


Fig. 21. Completed Rocker-arm properly welded

satisfaction. The use of small torches or gas burners in this or similar cases is of great assistance, because while they do not bring the piece to a red heat, yet enough of the chill is taken from the metal to save a considerable amount of welding gases, and this helps to make a better weld. It is evident that it would be quite difficult, if not impossible, to block up such a piece on the table and build up a charcoal fire under it, the heat being likely to warp or crack the table.

A Difficult Repair Job

Fig. 22 shows what frequently happens when some part of the connecting-rod in a motor lets go. This damage is generally the result of not keeping the rods tightened up as they should be. The case illustrated is not nearly as bad as some instances, but great care must be exercised in following the crack to the end. If the crack extends entirely through a piece, it will prevent the heat of the torch, when applied to one side, from passing to the other, with the result that where the piece is heated it will become red, while the other side will stay black; but if the crack extends only partly through, as is frequently the case, this test is valueless, and the only thing to do is to melt the iron in the direction in which the crack extends and pull it out with the welding rod. If there is a crack, it will show up as a white streak in the center of the melted portion. Therefore in all cases of this character, and in the case of jacket cracks, the weld should be made entirely through the piece at least 1 inch further than the crack shows on the surface, in order to be sure that the end is reached. In the present instance, the crack at corner *A* extended ¾ inch beyond where it was visible. The pieces were not prepared, nor is it the practice in the writer's shops to V the pieces in such cases.

Cylinders should always be heated slowly, and the base of the cylinder kept somewhat away from the fire, which should not be too heavy at the beginning. The cylinder should be tilted at an angle so that the heat will pass up through the bore and around the outside, underneath the asbestos paper with which it is covered. After the work is thoroughly warmed through, the defective part should be placed in the fire so as to become more thoroughly heated than the remainder. At this stage the heating should be watched carefully, and when it has arrived at the proper point, while the temperature is still rising, it should be welded in the fire. Under no circumstances must a cylinder be removed from the

Fig. 22. Automobile Cylinder with Dome broken and Jacket cut away in order to Reach Broken Portions

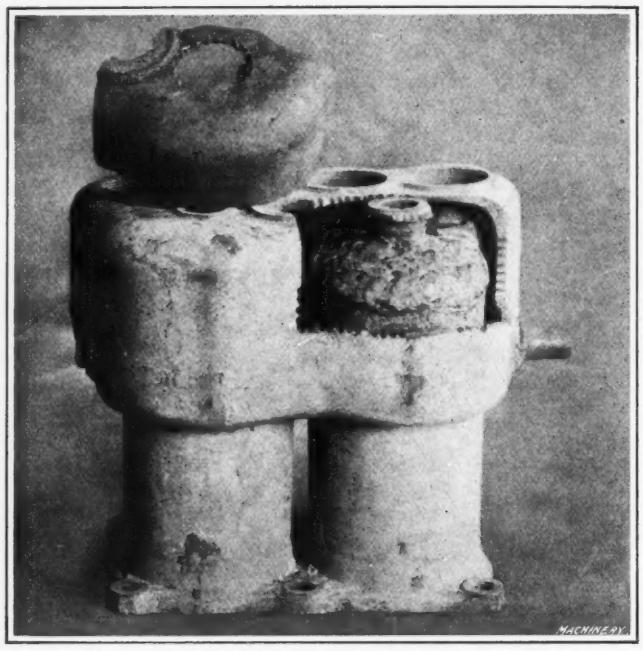


Fig. 23. Automobile Cylinder shown in Fig. 22 after Dome has been welded

fire while the weld is being made, and sufficient asbestos paper should be properly located to cover all the cylinder except the part being worked upon.

It is very difficult to explain how hot to heat a cylinder. If possible to avoid it, the heat should not be great enough to make it red at any point. In certain cases, the cylinder must be heated to a red heat, particularly where there is a rigid connection between the barrel and the jacket at several points, or where the cylinders have large flat sides. Frequently the proper temperature can be determined by the paint and filler on the cylinder being turned to a rusty brown powder. This test is only of value when the cylinder is on a rising temperature. It is evident, if it has been heated to this point and then allowed to cool, that it may not be warm enough to avoid shrinkage cracks, while it may appear so to the eye. The best way to obtain experience is to get some old cylinders and experiment with them. More can be learned in this way in a short time than by pages of description.

In this case, as soon as the cylinder arrived at the right temperature, which was higher than for an ordinary jacket crack—very close to a red heat—it was turned into the position shown in Fig. 22, and the pieces welded on. The welding began at *A*, went from there to *B* and *C* and so on back to the starting point. This gave the maximum chance for contraction to take place without difficulty. The weld was burnt completely through, and as soon as finished, the cylinder was turned over in the fire and the inside of the weld completed and smoothed off with a special torch. This is necessary in order to prevent pre-ignition in operation due to small points projecting into the cylinder becoming red hot, or to carbon collecting on such points and causing the same trouble. It is sometimes necessary to have more than one special torch to reach all the corners. Occasionally a cylinder broken in the dome is split part way down the barrel. Sometimes this weld can be made from the outside of the barrel, and the inside not welded. A better job, however, is made by welding on the inside as well as the outside, and afterward regrinding the cylinder.

After the dome was welded, the cylinder was packed away in powdered asbestos until it was cold; the proper openings were then plugged and the cylinder tested for leaks. This is always a safe precaution, because while, if the work is properly done, there is little chance for trouble, yet, if there is any difficulty, or if any crack is overlooked, it can be welded much more easily than if the jacket is welded right away. However, when time is an object, as it occasionally is, and if the welder is sure that he has welded the dome

Fig. 24. Cylinder in Fig. 22 with Piece of Jacket set in Place ready for Welding

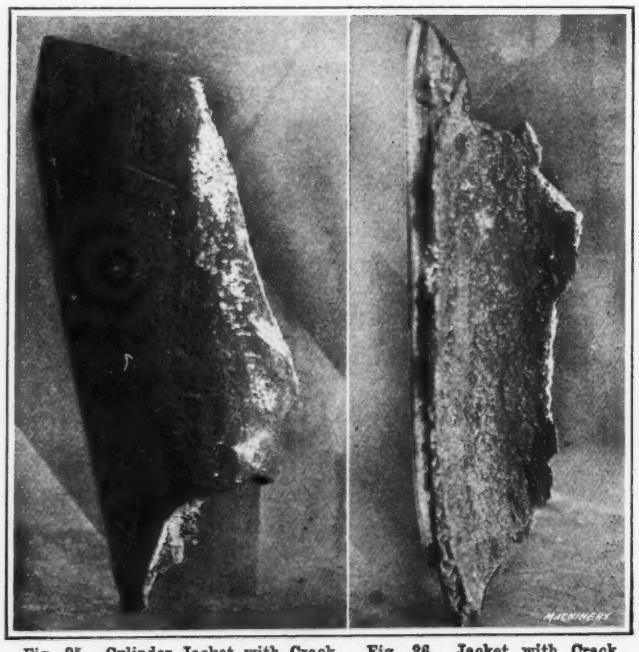


Fig. 25. Cylinder Jacket with Crack not Visible from Outside

Fig. 26. Jacket with Crack Clearly Visible from Inside

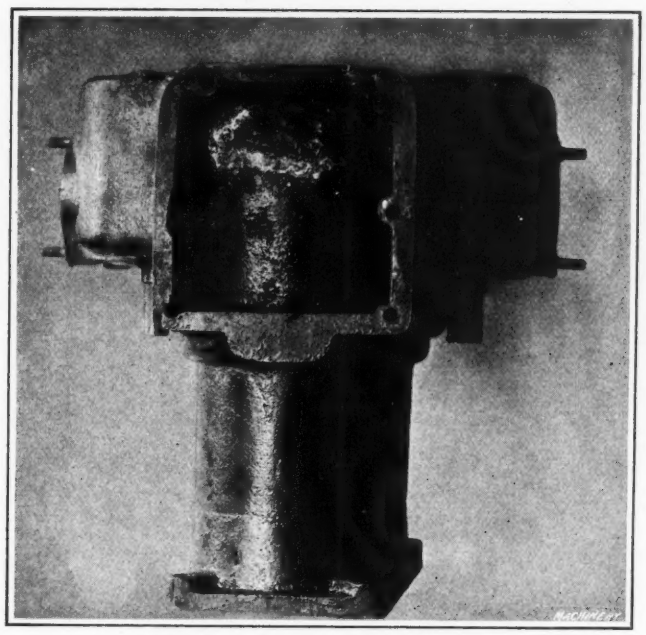


Fig. 27. Improperly Welded Cylinder

properly, the jacket may be welded at once, the whole cylinder packed in asbestos and allowed to cool.

After the cylinder was tested and everything found satisfactory, it was reheated, the jacket put in place as shown in Fig. 24 and welded, beginning at *A* and going to *B*, after which it was welded around the boss, again started at *B* and continued around to *C*. This took care of the contraction better than any other method. The surface *C* was set, before starting to weld, a little higher than *D* to allow of finishing the boss around the center hole.

Mention has been made of the possibility of a crack extending on the inside of a piece where it is not visible on the outside. A very good illustration of this is shown in Figs. 25 and 26, which show a piece broken out of an automobile cylinder jacket in order to weld the dome. In Fig. 25 a crack was visible at the top and bottom of the piece as a very fine line, but it was not visible for more than ⅜ inch in either case on the outside of the piece. However, it will be noticed that it extends along and is quite clearly visible inside in Fig. 26. This condition may exist not only in cylinder jackets, but in any other pieces of the same general nature, and the illustrations are shown to emphasize the necessity of following the crack all the way to the end.

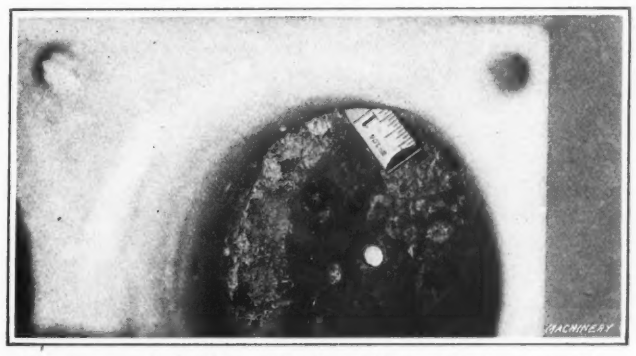


Fig. 28. Rough Condition of Inside of Dome of Improperly Welded Cylinder

Improper Welding of Cylinders

As an illustration of what results from improper welding of cylinders, Figs. 27 to 29 are shown. The original damage to this cylinder is indicated in Fig. 27, and consisted of a crack in the dome. From the appearance of the inside of the cylinder shown in Fig. 28, it looks as if the dome was broken in a number of pieces. It does not appear on examination of the cylinder whether the jacket was cut out to get at the broken dome, or whether it was broken out originally by the damage. However that may be, in attempting to put it back, the cracks kept on extending until the cylinder was cracked through two port plug holes. In addition to this, the corner of the cylinder as welded, was much flatter than it should be, the result being that it would have been impossible to grind out the cylinder without going through the weld. In addition to the above, there was no attempt made to smooth off the inside of the dome, with the result that the cylinder would have knocked, on account of pre-ignition due to the roughness. The cylinder as it stands is not beyond repair, if handled by one who knows how to do it, but the owner purchased a new cylinder, believing that it could not be fixed.

This is a good instance of the damage to the reputation of the oxy-acetylene welding process caused by those who do not know how to do the work and who have not the proper facilities. This cylinder was not preheated, and nothing else than what happened could have been expected. The possession of a hammer, chisel and monkey wrench does not make the owner a machinist; neither does the fact that one has a welding torch and oxygen and acetylene tanks enable him to weld anything that comes along. It should be emphasized that proper apparatus, instructions and training are necessary for the successful carrying out of work like that shown.

As a contrast to the foregoing, Figs. 30 to 33 are shown. Fig. 32 shows the damage to the dome, and the pieces of the jacket cut away to reach it. Fig. 30 shows, on the right, the pieces of the dome, and on the left the pieces of the jacket. In the center is shown the plug going through the top of the dome and jacket. It will be seen that the thread on this is badly damaged. The dome was broken into twelve pieces and the jacket into eight pieces. At *A*, *B*, *C* and *D* are shown the points where the four ribs extending between the dome and jacket are located, the ribs themselves not being shown.

The pieces are shown laid together on wet asbestos and carefully lined up. They were then "tacked" together with the torch so that they could be used as patterns for castings, the amount of welding all the pieces being too great; besides, it would be difficult to put the pieces accurately into place. On the castings from these patterns, as shown in Fig. 34, stock was left for finishing, except at the points *A*, *B*, *C* and *D*, where the connecting ribs between the dome and jacket had to be built up. Fig. 31 shows the dome welded in. Fig. 33 shows the jacket welded in and the dome plug with metal added on the threads. All the machining was done on an ordinary lathe. It was not possible to get exactly the same thread on the dome plug as on the original, but this made no difference, as the stock on the threads permitted any suitable thread to be used. It was impossible in this case to obtain a new cylinder, as the manufacturers had gone out of business; but the cost of repairs was considerably less than the cost of a new cylinder.

For the benefit of those who do not have any foundry located near them, it should be stated that the welding of the pieces together and setting them back into place is perfectly possible. They should all be welded together on both sides, the inside of the dome smoothed off by grinding, fitted in place and welded. In such cases enough of the jacket should

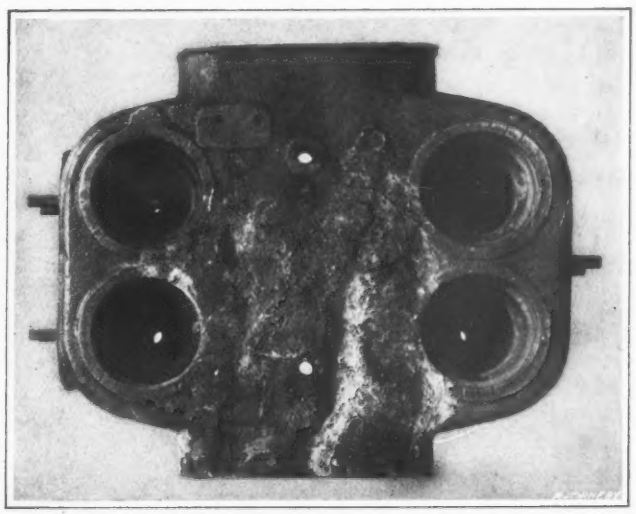


Fig. 29. Contraction Cracks in an Improperly Welded Cylinder

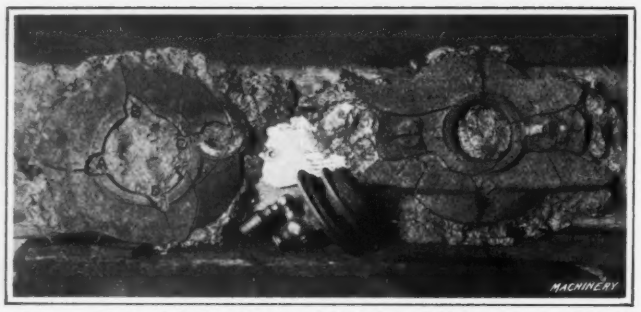


Fig. 30. Pieces of Broken Dome and Jacket of Cylinder shown in Fig. 32

Fig. 31. Dome welded in Place

be cut away at the beginning to enable the work to be done rapidly, and the planning should be done ahead, so that it will be known exactly how the work is to be handled. There is no necessity of having to plan these things while the work is being done.

Welding a Heating Boiler Casting

Figs. 35 to 39 show a section of a cast-iron heating boiler. Quite a number of these heater sections break, and as they are expensive, they are well worth welding. The reasons for their breaking generally come under three heads: 1. Allowing the water to become too low in the boiler. This permits the section to become red-hot, and when it is cooled off, or cold water turned in, a crack results. 2. Casting strains in the pieces. The writer has seen new sections not yet installed with bad cracks which certainly could not have passed inspection at the foundry. Sometimes, upon inquiry about a cracked section, the statement is made positively that the water was not low, and while this statement may not always be true, although the person making it believes it to be so, yet a sufficient number of cases have come to the writer's attention in which he believes the information to have been correct, to warrant the belief that strains in the casting are really a frequent cause of breakage. It is also well known that it is difficult to cast pieces of the shape of these sections without experiencing casting strains due to the difference in temperature of different parts while cooling off in the sand. 3. Strains are sometimes caused by the holes for the push nipples, which connect the sections, not being bored true, or in line; or if the sections are not put up correctly, the same trouble may exist. It is also possible to pull the sections together too tightly, and as the push nipples are tapered and fit in tapered holes, an enormous strain can be set up by too much tightening.

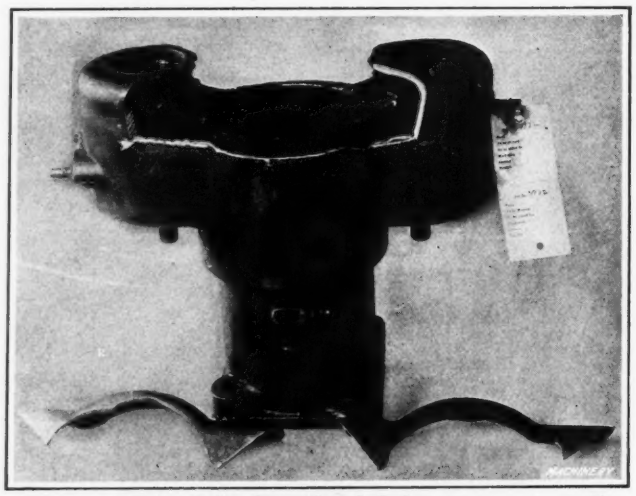


Fig. 32. Cylinder badly damaged and Jacket cut away to enable Welding to be done

Cracked heater sections are generally very difficult to weld, particularly if the cracks are in the body of the section. Of course, if only a corner is broken off, or if the section has a long leg on each side and the defect is in one of them, the difficulty is materially decreased. Considerable experience is required to make a sound permanent job, and even then satisfactory results may not be obtained at the first trial. The difficulties met with are the trouble of controlling the contraction when cooling, and of preheating correctly, if this is done locally, as well as the trouble of turning the section over while heating in order to reach the other side of the weld.

In order to overcome these difficulties, it is necessary, in the first place, according to the writer's experience, to heat the entire section red-hot; this heat must also be uniform. It is believed useless to spend any time trying to heat such a casting locally, or to provide for the contraction by heating one part somewhat more than another. The cause of the crack cannot always be known, and inasmuch as the real cause may be a combination of causes, the only safe way is to eliminate all strains by thoroughly preheating to a high temperature. The contraction while cooling may be overcome by slow cooling obtained by packing the welded casting in asbestos and thoroughly protecting it from drafts. In the case of large sections, this cooling may require forty-eight hours. If the work is to be done outside, in cold weather, great precautions must be taken to insure that the outside edges of the casting do not cool too quickly.

The difficulty of turning over the casting can best be overcome by providing special means for handling. What is done depends on conditions, and no fixed rule can be laid down; but the casting must be handled quickly, and if it is turned over, it must be allowed to reach to a uniform temperature before the final weld is made. After welding, the casting should again be brought to a uniform temperature and then carefully packed as outlined.

Fig. 35 shows a section in which the crack was probably caused by an original strain in the casting. The crack was barely visible, and in order to show in the photograph, it was necessary to wedge it open somewhat. There was some discussion in the shop as to just how to prepare the crack for welding. It was manifestly impossible to get any torch tip into the hole, which is about 1 inch in diameter, as the section

Fig. 33. Jacket welded in Place

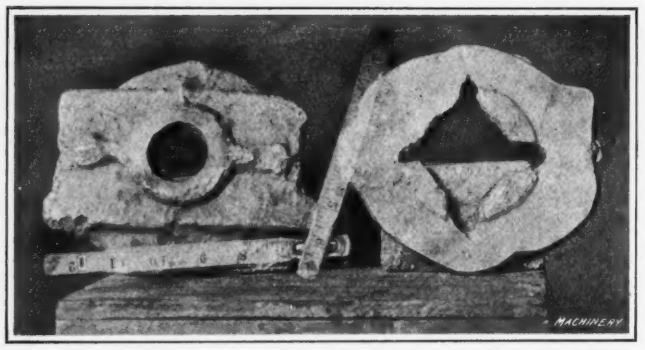


Fig. 34. Castings used in making Repairs shown in Figs. 31 and 33

Fig. 35. Crack in Section of a Cast-iron Heating Boiler

Fig. 36. Heating Boiler Casting prepared for Welding

was about 4 inches thick at that point. It was finally decided to prepare the casting as shown in Fig. 36, saving the piece that was cut out (the cutting being done by a hacksaw and hammer and chisel), so that it could be replaced. The wisdom of this method was apparent when the piece was removed, as it was found that there was a boss 1¼ inch thick around the 1-inch hole, the piece cut out of the boss being shown in Fig. 36 at *A*, while the main piece removed is seen at *B*. The boss can be seen in Fig. 38, where the section is shown laid on steel plates, blocked up from the concrete floor and with firebricks under the corners to leave space for the fire. The tram-marks will also be noticed at *A*, *B* and *C*, the distance *AC* being equal to *AB*, and being used as reference length.

Fig. 37. Heating Boiler Casting in which Weld is finished

Fig. 39 shows the use of old carbide cans cut up into strips of the proper size for confining the fire. These are very satisfactory for the purpose, as they can readily be bent to any shape and are inexpensive. The fire is applied to such a casting by lighting a considerable quantity of charcoal in a forge and shoving it underneath the casting, being sure to distribute it so as to obtain a uniform increase in temperature. This is a hard thing to do, and experience is the only guide.

It is evident that there is more chance for a draft around the outside of the casting than in the center, that a heavier section will require more charcoal than a lighter one, and that in the open spaces too much charcoal should not be applied. In this particular case, in spite of what was thought to be right, it was found that too much fire had been put along the part *AB*, Fig. 39, so that after the casting had become quite warm, the distance between the tram-marks had increased ⅜ inch. In order to remove the strain set up, the fire was shifted toward both ends, but still after the casting had become red, it was found that after allowing for expansion, the tram-marks had separated 3/16 inch, which indicated that there was a strain somewhere in the original casting.

When the charcoal was first placed underneath the section, care was taken not to use too much, and from time to time, as the casting became warm, it was added in small quantities, but more rapidly toward the latter part of the heating; of course, during all this time,

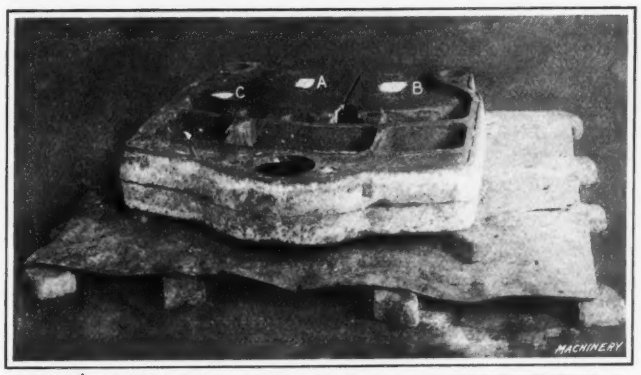


Fig. 38. Heating Boiler Casting showing Arrangement for Preheating

Fig. 39. Heating Boiler Casting ready for Preheating Fire to be started

Fig. 40. Upright of Broken Press Frame

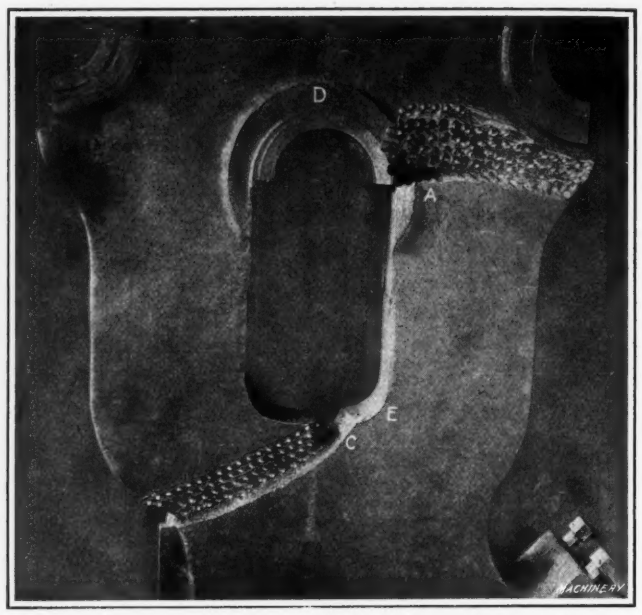


Fig. 41. Showing Breaks through Metal 5 by 17 and 5 by 14 Inches

the top of the casting was kept covered with asbestos paper. It is necessary, however, to punch holes in the paper to permit of sufficient draft to keep the charcoal burning. The paper tends to distribute the heat more uniformly.

The first welding done was to weld the boss. On account of the difficulty of reaching it, it was necessary to raise the casting from the fire and stand it on end, so that the work could be done quickly. It was carefully covered with asbestos paper while this weld was being made, then replaced in the fire and allowed to come to a uniform temperature. Then the piece which had been cut out was put into place, and the sides *C* and *D*, Fig 39, welded. The casting was then turned over, again allowed to come to a uniform temperature, and, beginning at what was then the bottom of the welds, the V's were filled up and the weld finished at the boss.

During the welding it was necessary to pack the top of the casting heavily with asbestos, as the welders had to stand over it to reach the bottom of the vertical welds. It always pays to protect the welders as well as possible in case of heavy fires, as if this is not done, they cannot do good work.

After the weld was finished, it was found that the trammed distance had increased ⅛ inch. Inasmuch as there was no strain in the casting after the work was done, as it had been uniformly heated after welding, this ⅛ inch represented the total amount of strain in the casting. Where it was, it is impossible to say, but it evidently was there. When cold, a thorough hammer test with a light sledge was made, as well as a pressure test, and everything was found to be in good condition.

It is evident that this ⅛-inch expansion had to be taken care of, as the push nipples could not be put back in place if it were not. The following method of taking care of it has been found in all cases to be entirely satisfactory. The push nipples are made either of cast iron or steel, and the method followed is to cut the nipple in half with a hacksaw. The section is erected in place with each half of the push nipple in its respective hole. A line is then carefully scribed with a sharp point along the exposed surface where the two halves offset, the pieces removed and welded to suit their new position. If this is carefully done, it will be found that the result is entirely satisfactory.

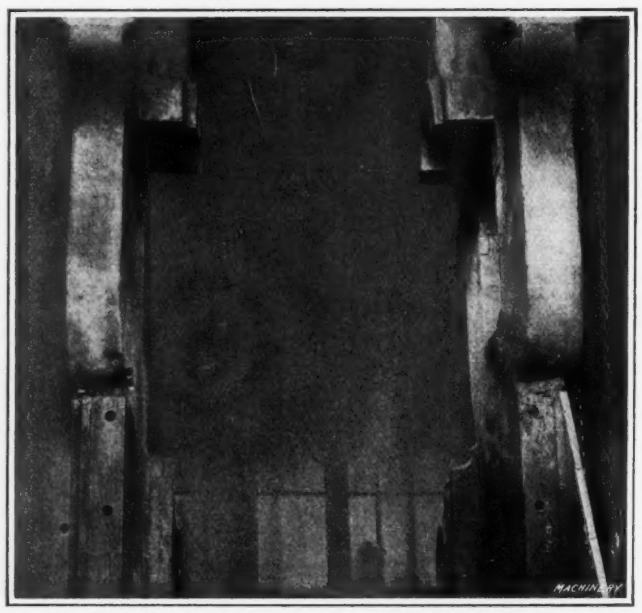


Fig. 42. Press Frame showing Breaks prepared for Welding by drilling and chipping Metals

Welding a Press Frame

Fig. 45 shows a large press frame which is broken. The top of it is very close to the wooden roof of the building. Inasmuch as it would have been quite expensive to remove the casting, it was thought wise to attempt to weld it in place. Fig. 40 shows the size and nature of the breaks, the bottom of one of which was comparatively easy to reach, both to prepare and weld.

Fig. 41 shows that the top break was prepared nearly through the casting at the point *A* from the side shown, while at *B* the preparation was made equally on both sides. This was done in order to save the bearing. It will be noticed from Fig. 45 that the bearing on the inside of the broken side had a large projection, and nearly half of this would have had to be cut off if the bevel had been prepared evenly on both sides.

The heating of these breaks, particularly the upper one, was quite a problem, and trouble was anticipated in controlling the contraction, partly because the upper part of the casting was much heavier than the lower part, and also because, as it was very close to the wooden roof, it was feared that sufficient heat could not be applied to raise the casting to the same temperature as below; that this fear was justified was proved by the results. However, it was determined to make the attempt, a plan having been worked out whereby, if trouble should occur, it could be overcome. The heating was done by pans made of old carbide cans hung by wire from the upper part of the casting and surrounding the welds. These pans were located to get as uniform an expansion as possible, and while the breaks shown in Fig. 41 were being welded, fire was maintained in pans on the opposite side in order to avoid any irregular strains due to vertical contraction. It was, however, not anticipated that any trouble would come from the vertical contraction. The difficulty feared was the difference between the horizontal contractions at *C* and *D*, Fig. 41. It is evident that section *C* is much lighter than *D* and that in order to extend the castings the same amount, a much heavier fire would have

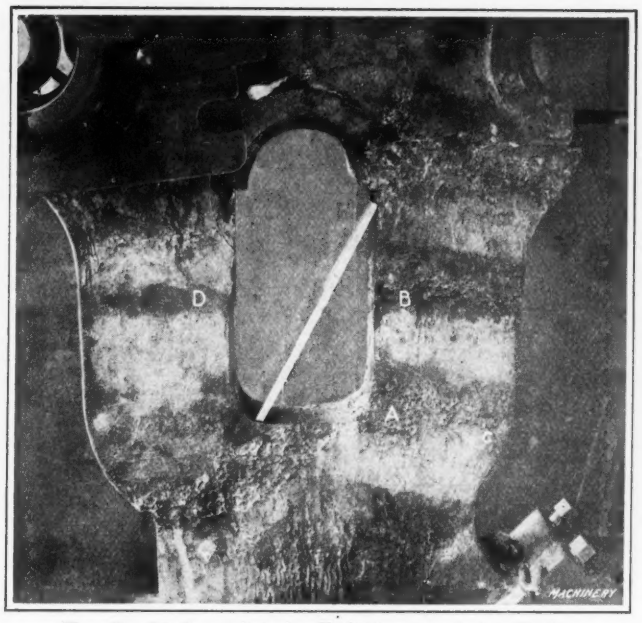


Fig. 43. Crack on Opposite Upright prepared for Welding

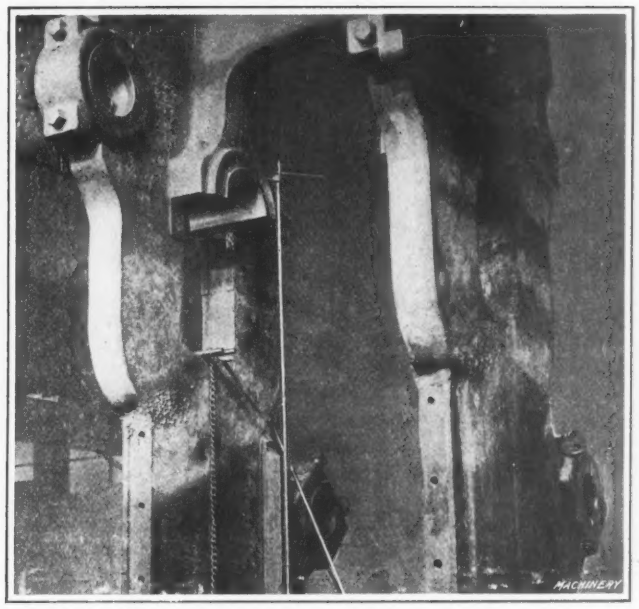


Fig. 44. Section of Press Frame after Welding

to be maintained at the latter point than at the former. While the pans were placed entirely across the top at *D*, it was found impossible with as heavy a fire as could be kept up, to get the same amount of expansion horizontally, although the width of the fire was about 4 inches all around the casting, except at *E* where the pan was cut off to allow the casting to stay as cool as possible. In other words, the lower pan went no further than the break, while the upper pan not only covered the break but also the opposite side of the casting.

In spite of these precautions, and while no new cracks appeared directly after the welds were made, a hammer test later developed a crack at *A*, Fig. 43. This was the result anticipated. The solution of the trouble was to first cut the casting entirely through, as at *B*, and weld *A*. The crack at *A* only extended about 4 inches from the inside corner, but the V was made on both sides about 1½ inch deep at *C*, in order to insure uniform heating with the torch. It was an easy matter to place a pan opposite *B* and one at *D*, and also two others opposite *B* and *D* on the other side of the frame. The desired expansion was obtained without any trouble, and the casting welded at *B*; the tram-marks showed that the casting came back to its original position.

In Fig. 42 will be seen the preparation of a small crack on the left upright. This gave no trouble in welding, as the large body of metal left forced the expansion to take place as was desired. However, the precaution to heat the other upright also was taken while welding. The whole casting weighs about twelve tons.

The problem in this case was to do the welding without removing the frame. There would have been no trouble in welding it had it been removed, because not only could the different parts of the casting be brought to a uniform temperature, but as the welding would have been done horizontally, it would have been much easier. As it was, all the metal had to be added on the side. The two main breaks required four welders for a period of twenty-two hours, as the heat was very great due to the low roof which it was necessary to protect from damage by fire, and also due to the fact that the space between the uprights was only about three feet, so that part of the time the men were working between the pans on the upright.

There was a shrinkage strain in the original casting; this made it necessary to rebore the bearings. It was, of course, realized before the job was started that this would have to be done. This frame has been in service several months since welding, and has been subjected to heavier work than ever before, with entirely satisfactory results.

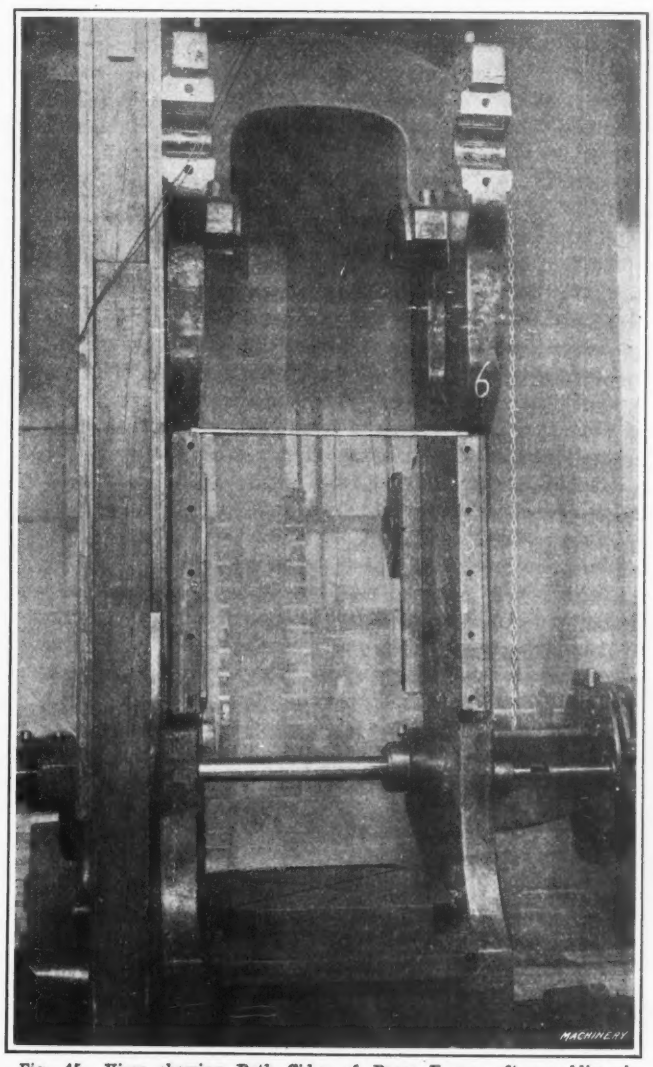


Fig. 45. View showing Both Sides of Press Frame after welding is completed and Bearings have been repaired

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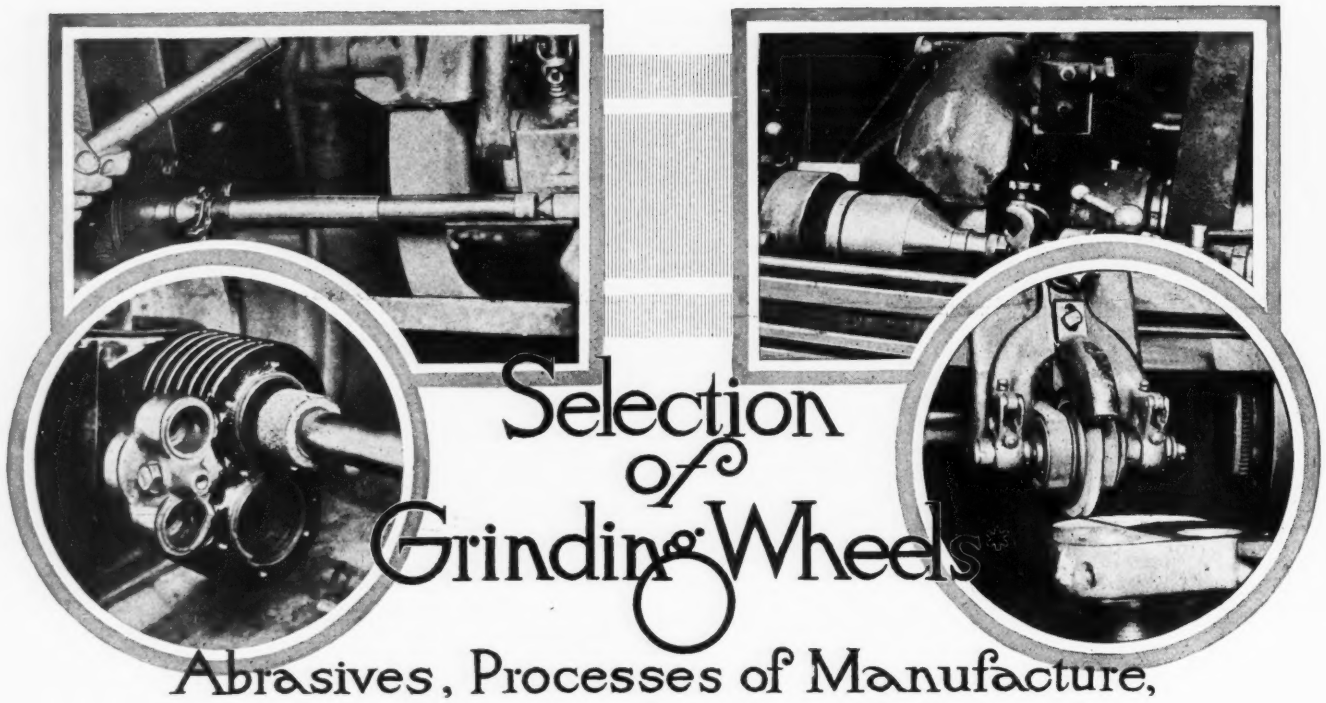
SWAGING HEXAGON HOLES

The hexagon holes in one make of safety set-screws are neatly shaped in a punch press operation. The screws are blanked on screw machines, the hole for the wrench being drilled to a diameter equal to the distance across the corners of the hexagon desired. The exterior of the screw is turned to two diameters, that at the point being the external thread diameter. The body of the blank is turned sufficiently larger than the point to reduce to the external thread diameter when the hexagon socket is swaged. The swaging is done in a punch press, using a hexagon punch which, seated in the hole, pushes the blank through a die. The die reduces the diameter and the excess metal is forced inward against the punch, which acts as a former. The blank, thus reduced to the correct external thread diameter throughout its length, is threaded in a bolt cutter.



Selection of Grinding Wheels

Abrasives, Processes of Manufacture, Bonds—Choosing Grade and Grain for Grinding Under Varying Conditions

by Douglas T. Hamilton †

THE modern grinding wheel, when properly selected for the work upon which it is used, is very efficient, especially for the finishing of accurate work. The developments in the manufacture of grinding wheels within the past few years have assisted in placing the grinding machine in a class with other highly productive tools and have made possible great decreases in manufacturing costs. A grinding wheel may be compared to a milling cutter having an infinitely greater number of teeth or cutting points. For instance, on an average wheel 24 inches in diameter and 4 inches face, approximately, 1,086,171,000 cutting points come into contact with the work each minute. The teeth or points that do the cutting are called "grains", whereas the material used for holding the grains in the form of a wheel is called the "bond".

Grade of Grinding Wheels

The term "grade", as applied to a grinding wheel, refers to the tenacity with which the bond holds the abrasive grains in place, and does not refer to the hardness of the abrasive. A wheel from which the abrasive grains can easily be dislodged is said to be soft or of soft grade, whereas one which holds the grains more securely is called a "hard wheel." By varying the amount and composition of the bond, wheels of different grades are obtained. The hardness of the wheel is also governed to a certain extent by the size of the grains; for instance, if two wheels have the same bond, the one composed of the finer grains of abrasive is the harder. In other words, a 120-grain wheel would be harder than a 24-grain wheel of the same bond. The combination of different sized grains also causes a variation in the hardness of the wheel.

Grinding Wheel Grading Systems

The grade of a grinding wheel is designated either by letters of the alphabet or numbers, or a combination of both, as will be seen by referring to Table I. According to the system employed by some manufacturers, the letter M represents a medium grade, and the successive order of letters or numbers preceding and following M denote softer or harder wheels. This method of grading wheels is not universal, as no standard system of grading has been adopted by the various manufacturers.

Table I gives lists of grading letters and numbers used by the principal grinding wheel manufacturers, and in this connection it should be clearly understood that these should not be used on a comparative basis. In the first place, the present method of grading wheels is not a mechanical test, but is done by hand as shown in Fig. 1, and requires considerable skill and experience. The tool used has a ball-shaped handle and a blade which is beveled on the end like a cold chisel. When making the test, the beveled end of this tool is simply pressed into the side of the wheel and then turned. The resistance offered by the bond of the wheel to this twisting action indicates, to the experienced man, the grade of the wheel. The extremely delicate sense of touch essential is soon lost even by an expert, who finds it necessary to discontinue the work now and then for a short time.

Considering the method used in testing, it is not surprising to find that the grade letters or numbers adopted by different manufacturers cannot be used interchangeably. A few examples will probably make this point clear. Careful comparison of the grade marks used by the Norton Co. and the American Emery Wheel Works has shown that a grade L American wheel agrees closely with a Norton L wheel as to hardness, but by referring to Table I it will be noted that

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* For additional information on grinding, see the following articles previously published in MACHINERY: "Surface Grinding," September, 1915; "Internal Grinding," August, 1915; "Plain Cylindrical External Grinding," July, 1915; "Holding Roller Bearing Races for Internal Grinding," May, 1915; "Grinding Practice," February, 1915; "Selection of Wheels for Cylindrical Grinding," January, 1915; "The Tolford Ball Grinding Machine"; "Grinding vs. Milling"; "Operation of Grinding Wheels in Machine Grinding"; "Data on Surface and Cylindrical Grinding," December, 1914; "Ring Wheels and Solid Wheels for Disk Grinding"; "Wheels for Cylindrical Grinding," November, 1914; "Grinding and Lapping Small Work"; "Selection of Wheels for Cylindrical Grinding," October, 1914; "Making Aloxite Grinding Wheels," September, 1914; "Lobdell Calender Roll Grinding Machines"; "Work-holding Fixtures for the Vertical Surface Grinder"; "Crankshaft Grinding," August, 1914, engineering edition; "Safety as Applied to Grinding Wheels," July, 1914, engineering edition, and other articles there referred to; "The Use of Photographs in Grinding and Polishing Departments," July, 1914; "Work Speeds in Grinding," April, 1914; "Machining Armature Shafts," February, 1914; "Grinding Wheel Protection Devices," January, 1914, engineering edition; "Fixture for Grinding Valve Push Rods," June, 1913; "Exhaust System for Grinding, Polishing and Buffing Wheels"; "A Three-Point Micrometer and Its Use," May, 1913; "Efficient Grinding of Cylindrical Work," December, 1912; "Commercial Grinding," October, 1912; "Grinding Calender Rolls," August, 1912; "Grinding and Corrugating Flour Mill Rolls," July, 1912; "Internal Grinding Practice in Hardinge Bros. Shop," May, 1912; "Holding Work for Grinding"; "Efficiency in Cylindrical Grinding," March, 1912; "Grinding Aluminum Castings on a Vertical Spindle Disk Grinder," January, 1912; "Grinding Hardened Gears," September, 1911; "The Field for Grinding—A Comment," July, 1911; "Rough-turning vs. Rough-grinding of Crankshaft Pins," March, 1911; "The Field for Grinding"; "Precision Grinding," January, 1911; "Grinding Adding Machine Side Frames," December, 1910; "Grinding Economy," July, 1910; "History of the Invention of the Universal Grinding Machine," July, 1910, engineering edition; "Grit and Grinding Chips," June, 1910, engineering edition; "Economy in Grinding," May, 1910; "Errors in Grinding Tapered Reamers and Milling Cutters," December, 1909; "Form Grinding Operations in the Shop of the Landis Tool Co.," August, 1909; "Twist Drill Grinding," June, 1909; "Cylindrical Grinding," May, 1909; "Grinder Kinks," December, 1908; "Grinding Threading Chasers for Brass Work," November, 1908; "Devices for Grinding Fluting Cutters," October, 1908; "Helps and Don'ts for Grinding," August, 1908; "Grinding Threading Dies," December, 1907; "Grinding Threading Die Chasers," November, 1907; "Precision Grinding," September, 1907.

the Norton grade L wheel is graded as fourth in the "medium soft" column, whereas the "American" L wheel is graded as third in the "soft" column. The grade marks used for wheels made by the various processes also indicate different grades, although the wheels in each case may be known as soft, hard, etc. For instance, in the Norton list a grade 1 elastic wheel is not of the same hardness as a grade E vitrified or silicate wheel, although both are called soft wheels.

Fig. 1. Method of determining Grade of Grinding Wheels

Grain of a Grinding Wheel

The grain or coarseness of a wheel is designated by numbers which indicate the number of meshes to the linear inch through which the kernels of abrasive will pass. For instance, 36 grain means that the abrasive will pass through a sieve having 36 meshes to the linear inch. The grains commonly used for plain cylindrical grinding vary from 24 to 60. There are two kinds of grains—straight and combination. In a straight-grain wheel all the particles of abrasive are of about the same size, whereas in a combination grain wheel the particles of abrasives are of different sizes. The combination of grains in a wheel is never specified by a manufacturer, as it requires considerable experimenting to determine the correct proportions for any combination. Sometimes a number is arbitrarily selected to indicate the combination of grains, whereas in other cases the number given indicates the coarsest grain in the wheel. A correct combination of grains cuts fast and leaves a good finish on the work; moreover a combination wheel will generally remain in a good cutting condition longer than a straight-grain wheel.

Abrasives Used in the Manufacture of Grinding Wheels

The abrasives used in the manufacture of grinding wheels are both natural and artificial. The chief natural abrasives are emery and corundum. Those artificially produced are adamite, aloxite, alundum, boro-carbone, carborundum, carbolite, crystolon, etc. Of the natural abrasives, corundum is the most widely used; it contains a much larger percentage of crystalline alumina, than emery does, this being the element in both abrasives that does the cutting. Emery is very tough, but contains iron and other non-cutting elements, and is seldom used in wheels employed on automatic grinding machines. With the exception of corundum, most of the

TABLE I. GRADING SYSTEMS USED BY GRINDING WHEEL MANUFACTURERS TO INDICATE HARDNESS OF BOND IN GRINDING WHEELS

Grade	GRINDING WHEEL MANUFACTURERS																			
	Abrasive Material Co.		American Emery Wheel Works			Carborundum Co.		Cortland Corundum Wheel Co.		Detroit Grinding Wheel Co.		Norton Co.		Safety Emery Wheel Co.		Sterling Grinding Wheel Co.		Vitrified Wheel Co.		Waltham Emery Wheel Co.	
	Grade Index of Grinding Wheels used for Different Processes of Manufacture																			
	Vit. and Sil.	Elast.	Vit.	Sil.	Elast.	Vit. and Sil.	Elast.	Vit. and Sil.	Elast.	Vit. and Sil.	Elast.	Vit. and Sil.	Elast.	Vit.	Sil.	Vit. and Sil.	Elast.	Vit. and Sil.	Elast.	Vit. and Sil.	Elast.
Extra Soft	G	¾E	..	..	..	Z	..	D	D	C	1/2	..	..	C	6	1	1	..	..	..	..
	..	..	..	..	..	Y	..	E	E	D		..	..	C½	..	1¼	1¼	..	..	..	..
	..	..	..	..	..	X	..	F	F	..	..	..	..	..	..	..	..	..	..	..	..
Very Soft	H	1E	G	½	½E	W	11	..	..	..	..	..	..	H	5½	1½	..	..	..	..	..
	I	..	H	¾	¾E	V	10	..	..	E	¾	..	..	H½	5	1¾	..	..	..	..	..
	..	..	I	1	1E	U	..	..	..	F		..	..	..	..	..	..	..	..	..	..
Soft	J	..	J	1½	1½E	T	9	G	G	G	1	E	1	A	4½	2	2	C	½E	1½	1½R
	K	1½E	K	2	2E	S	8	H	H	H		F	1½	A½	..	2¼	2¼	C1	1E	1¾	..
	..	..	L	2½	2½E	R	..	I	I	..	..	G	..	A¾	..	..	2½	C2	1½E	2	..
	..	..	..	..	..	..	..	..	..	..	..	H	..	A1	..	..	2¾	..	..	..	..
Medium Soft	..	..	..	..	..	P	7	J	J	..	..	I	2	M	4	2½	..	C3	2E	2¼	2R
	L	2½E	..	..	..	O	6	K	K	I	1½	J	2½	M¼	..	.	..	D	2½E	2½	..
	..	..	..	..	..	N	5	L	L	K		K	..	M½	..	..	..	D1	3E	2¾	..
	..	..	..	..	..	..	..	..	..	..	..	L	..	M¾	..	2¾	..	D2	..	3	..
Medium	M	3½E	M	3	3E	M	..	M	M	L	2	M	3	P	3½	3	3	D3	3½E	3¼	2½R
	..	..	N	3½	3½E	L	4	N	N	M		N	4	P¼	..	3¼	3¼	E	4E	3½	..
	..	4E	O	4	4E	K	3	O	O	..	..	O	..	P½	..	..	..	E1	4½E	3¾	..
	..	..	..	..	..	J	..	..	..	..	..	P	..	P¾	..	..	..	E2	..	4	..
Medium Hard	N	5E	P	4½	4½E	I	..	P	P	..	..	Q	5	1	3	3½	..	E3	5E	4¼	2¾R
	O	6E	Q	5	5E	Ix	2	Q	Q	N		R	..	1¼	..	..	..	F	5½E	4½	..
	P	7E	R	6	6E	H	1	R	R	P	2½	S	..	1½	..	..	..	F1	..	4¾	..
	..	..	..	..	..	Hx	..	..	..	..	..	T	..	1¾	..	3¾	..	..	..	5	..
Hard	Q	..	..	..	..	G	½	S	S	Q	3	U	V6	O	2½	4	3½	F2	6E	5½	3R
	R	..	..	..	..	Gx	..	T	T	R	4	V	V7	O¼	2	..	3¾	F3	6½E	..	..
	..	..	..	..	..	F	..	U	U	..	..	W	..	O½	..	..	..	..	..	..	..
	..	..	..	..	..	E	..	..	..	..	..	X	..	O¾	..	4¼	..	..	..	..	..
Very Hard	S	..	S	7	7E	D	..	..	..	..	..	..	..	N	1½	4½	4	G	..	..	3¼R
	T	..	T	..	..	..	..	..	..	..	..	..	..	N¼	..	..	4¼	..	..	..	..
	U	..	U	..	..	..	..	..	..	T	5	..	..	N½	..	..	4½	..	..	..	..
	..	..	..	..	..	..	..	..	..	U	6	..	..	N¾	..	4¾	4¾	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Extremely Hard	V	..	V	..	..	..	..	V	V	..	..	Y	..	E	1	5	5	..	..	6	..
	..	..	..	..	..	..	..	..	..	..	..	Z	..	E¼	..	5¼	5¼	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	E½	..	5½	5½	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	E¾	..	5¾	5¾	..	..	..	..
Special Extra Hard	Z	..	..	..	..	..	..	..	..	..	..	..	..	D	..	6	6	..	..	..	4R

Machinery

Note: This list of wheel gradings as given by the various manufacturers should not be used on a comparative basis.

abrasives used in grinding wheels are produced artificially in the electric furnace from bauxite and carbide of silicon. The chief constituents and methods of manufacture of a number of the natural and artificial abrasives—designated by various trade names—are given in the following:

Adamite is an artificial abrasive produced in Austria and used by the Detroit Grinding Wheel Co. The chief constituent is aluminum-oxide, which is mixed with certain ingredients to remove the impurities and is fused at a high temperature in the electric furnace. This abrasive is used in wheels for grinding materials of high tensile strength, such as soft and hardened steel, etc.

Alundum is an artificial abrasive first produced by Charles B. Jacobs, consulting electro-chemical engineer. The original process, however, has been perfected and commercially applied by the Norton Co. Alundum is made by fusing the mineral bauxite in the intense heat of the electric arc furnace. Bauxite is a soft earth resembling light yellow clay, and, chemically, is the purest form of aluminum-oxide found in nature. It is one of the most commonly occurring substances in nature and is usually found mixed with other materials from which it is exceedingly difficult to separate it. Separation was impossible previous to the invention of the electric furnace. Bauxite derives its name from the ruined city and castle of les Baux, in the southern part of France, where it was originally discovered. Large quantities of this mineral are now mined in Georgia, Alabama, and Arkansas. It is found in pockets and is mined in open cuts, then carefully washed, dried and shipped to the plant where it is purified and subsequently fused in the electric furnace. Alundum is used in wheels for grinding materials of high tensile strength. A special temper or "white" alundum is used by the Norton Co. in the manufacture of wheels for certain classes of work. This is designated as No. 38 to distinguish it from ordinary alundum.

Alowalt is a trade name given to an abrasive used by the Waltham Emery Wheel Co., which is the product of the electric furnace and is made from aluminum-oxide in practically the same manner as aloxite.

Aloxite is the trade name given to an abrasive manufactured by the Carborundum Co. that is made from pure crystalline aluminum-oxide, produced by fusing bauxite in the electric arc furnace. In converting bauxite to aloxite, three operations are necessary: first, the removal of approximately 15 per cent of moisture; second, the removal of iron and silica; and third, the changing of amorphous bauxite into crystalline aloxite. Bauxite is received from the mine in small lumps, and after being crushed it is calcined in rotary kilns, fired with producer gas, which removes the moisture and volatile matter. It is then mixed with a certain percentage of coke, after which it is placed in the electric furnace. The furnace consists of a crucible-shaped steel receptacle, about five feet in diameter, which is lined with carbon and is movably mounted. The top is open and two vertical carbon electrodes extend down into the charge, which is fused between the arcs formed by the electrodes. The electric arcs generate a temperature estimated to be about 4000 degrees F. The charge of bauxite is fed into the furnace from time to time until an ingot has been formed weighing several tons. The current is then shut off, and the mass allowed to cool slowly. The ingot is then removed, freed from unfused mixture and metallic reduction products, and broken into small blocks. It is then crushed, concentrated and graded, and mixed with the bond ready for molding, truing and burning. Aloxite is used for grinding materials of high tensile strength.

Boro-carbone is the trade name for an abrasive used by the Abrasive Material Co. which is also a product of the electric arc furnace. It is manufactured in southern France and is oxide of aluminum in crystalline formation produced by fusing bauxite at a temperature of about 3800 degrees F. The temper of boro-carbone is varied according to the kind of work on which it is to be used, and its physical formation is such that it presents sharp cutting points when fractured. It is used for grinding materials of high tensile strength.

Carbide of silicon is the name given to an abrasive used by the Abrasive Material Co. in making grinding wheels for materials of low tensile strength, such as cast iron, brass, etc. The chief constituents of this abrasive are coke and sand. The coke supplies the carbon and the sand the silicon. These two substances are volatilized in the electric furnace.

Carbo-alumina is the name of an artificial abrasive used by the Detroit Grinding Wheel Co. in the manufacture of wheels for grinding materials of high tensile strength. It is produced from bauxite in a somewhat similar manner to alundum.

Carbolite is the trade name given to an abrasive used by the American Emery Wheel Works in the manufacture of wheels for grinding materials of relatively low tensile strength, such as cast iron, brass, aluminum, etc. Carbolite is another name for carbide of silicon in crystalline form, and is made from coke and sand which is volatilized in the electric furnace.

Carbolon, which is manufactured by the Exolon Co. and sold by Alden Speare's & Sons Co., is used by the Vitrified Wheel Co. in the manufacture of wheels for grinding materials of low tensile strength. Pure silicon carbide is a hard crystalline material in which the individual crystals are arranged in comparatively thin transparent layers of a greenish hue. Commercially, silicon carbide may be of a greenish hue, black, or highly colored. The black variety frequently has extremely thin layers of impurities, such as metallic silicon, metallic iron, etc., deposited between the crystalline layers. Carbolon is made from coke and sand in the electric furnace in a manner similar to carbolite. It has been found that an accurate control of temperature in the reaction zone of the furnace is of the utmost importance, and also that the slightest variation in the mixture of raw materials produces a marked effect on the nature of the resultant crystalline mass.

Carborundum is the trade name given to an artificial abrasive manufactured by the Carborundum Co., which is a chemical combination of carbon and silicon, discovered by Edward G. Acheson in 1891. The principal materials used in the manufacture of carborundum are coke and sand. The coke is used to supply the carbon, and the sand the silicon. These two substances are raised to a temperature of about 7000 degrees F. All the impurities and other substances in the coke and sand other than carbon and silicon are driven off in gaseous form, and these two elements unite, forming the abrasive known as carborundum.

Carbowalt is the name of an abrasive used by the Waltham Emery Wheel Co. It is manufactured from coke and sand in a somewhat similar manner to carborundum.

Corex is the trade name for an abrasive used by the Safety Emery Wheel Co. in the manufacture of wheels for grinding cast iron, unannealed malleable iron, brass, bronze, etc. It is produced from coke and sand in the electric furnace.

Corowalt is a special temper corundum abrasive used in the manufacture of grinding wheels by the Waltham Emery Wheel Co. It is especially useful for the grinding of hardened low or high carbon steel. It is produced in the electric furnace in a manner similar to alundum.

Corundum is the purest of natural abrasives and is a mineral composed of native alumina, which is noted for its hardness. This mineral was first found in India in the eighteenth century, and derives its name from a native Indian name, kurundam. The finely colored transparent varieties of this abrasive include such gems as the ruby and sapphire, while the impure granular and massive forms are known as emery. Next to the diamond, corundum is the hardest known mineral. Large deposits of this mineral are found in Georgia and North Carolina, and also in Ontario, Canada. Corundum is also produced artificially, although it is artificial only in the sense that it is crystallized by means of the electric arc furnace instead of by nature. Chemically, natural and artificial corundum are alike, both being composed of aluminum oxide in the crystalline form. A special grade of artificial corundum made by the American Emery Wheel Works is known as No. 58 to differentiate it from the natural corundum. Artificial corundum was first made by Moissan, in Paris, in the electric furnace, about twenty-three

years ago. Shortly afterward, the original process was improved by Werlem and patented in France. By these improvements, the impurities in the natural alumina were removed in the crystallizing process, so that practically pure crystalline alumina was the result. Wheels made from artificial corundum are either given a trade name, such as "Oxaluma," or are designated by some number to distinguish them from wheels made from natural corundum. For instance, for grinding certain materials, such as steel, etc., the American Emery Wheel Works produces an abrasive known as No. 58 corundum.

Crystolon is an artificial abrasive produced by the Norton Co., the chief constituents of which are carbon and silicon. Crystolon is made from coke, sand, sawdust and salt. Coke is used to furnish the carbon element; the silicon comes from a pure silica sand which is secured from large deposits in Illinois. Crystolon is a very hard brittle abrasive, and ranks next to the diamond in hardness. It is a mass of gray or green multi-hued crystals of attractive appearance. The elements previously mentioned are fused in an electric furnace, at a temperature varying between 3500 and 4500 degrees F., the sand and coke combining to form carbide of silicon. This abrasive is used in the manufacture of wheels for grinding cast iron, brass, bronze, etc.

Emery is a natural abrasive, and is an intimate mixture of corundum (oxide of aluminum) and magnetite or hematite (oxide of iron). It usually occurs in large irregular masses resembling a fine grain of iron ore, which it was originally thought to be. In the Grecian and Turkish mines it occurs in nodules or irregular masses, some of which are several yards in diameter and average about 40 tons in weight. Prior to 1847 all emery used throughout the world came from the Grecian Isle, principally from the Isle of Naxos, but in 1847 Dr. J. Lawrence Smith of Louisville, Ky., discovered considerable masses of emery ore in Asiatic Turkey. Emery is also mined in Chester, Mass. Emery is classed as a form of corundum, corundum itself being divided into three classes, viz., sapphire, comprising the transparent form, such as the ruby and sapphire; corundum, comprising the translucent form, such as commercial corundum; and emery, comprising the massive and black or dark colored varieties. Emery is a very tough and durable abrasive, but contains iron and other non-cutting elements, and is seldom used in grinding wheels for use on automatic or semi-automatic grinding machines. Analysis of emery obtained from the three principal sources showed the following percentages of crystalline alumina: Naxos emery, 63 per cent; Turkish emery, 57 per cent; Chester emery, 55 per cent.

Oxaluma is a trade name given to an aluminum-oxide abrasive used by the Cortland Corundum Wheel Co. in wheels for grinding materials of high tensile strength, such as soft or hardened steel, etc.

Rex is the trade name for an aluminum oxide abrasive used by the Safety Emery Wheel Co. in wheels for grinding either soft or hardened steel. This abrasive is the product of the electric furnace, the process of manufacture being similar to that of alundum.

Bonding Processes Used in the Manufacture of Grinding Wheels

By the use of different abrasives, grinding wheels can be produced which are adapted to a variety of purposes. The important properties of an abrasive are hardness, toughness, absence of impurities, uniformity and "fracture" or sharpness. Inasmuch as these qualities vary to some extent in different abrasives, grinding wheels may be produced which possess varying characteristics, and therefore are effective in grinding not only metals of different compositions but various other materials. The characteristics of a grinding wheel can also be changed by using different bonds, the bond being the substance which holds the abrasive grains together. The three most important bonding processes are known as the vitrified, silicate and elastic processes, and these names are applied to the wheels. For instance, a wheel made by the vitrified process is commonly referred to as a vitrified wheel. Other processes occasionally employed are the vulcanite process, the celluloid process, and the oil process.

The first abrasive wheels known were natural stones, but the uses of these were greatly limited because they did not possess the required physical properties for the efficient cutting of metals. Subsequently, artificial abrasive wheels for grinding metals were bonded with hydraulic cement, which did not prove very satisfactory. Attempts were then made to use organic substances which melt when heated and become hard when cold. Shellac-, resin-, sulphur-, and rubber-bonded wheels were then tried, and, of these, shellac and rubber were successful to a certain degree. The next advance was to use silicate of soda, and the vitrified or fused clay processes. These two processes are largely used today, the latter chiefly in the manufacture of wheels for use on automatic grinding machines.

The Vitrified Process

As vitrified grinding wheels are used to a greater extent in connection with machine shop practice than those made by the silicate or the elastic process, the manufacture of wheels by this process will be described at some length. The bond consists of suitable clays—generally a pure grade of kaolin, which is a clay used in the manufacture of porcelain. When the material for vitrified wheels is mixed by the wet process, power-driven kettles are used. When the mixture attains the consistency of thick paint, it is transferred from the mixing kettle to a mold. When the mold is full, the mixture is carefully worked to remove all air bubbles and insure a solid wheel. The molds are then partially dried in an open room to prevent formation of cracks. This preliminary drying is followed by a more complete drying in the heated room. When the molds of the wheels are hard enough to be handled, they are ready to be turned to shape preparatory to burning in the kiln. The wheels are, of course, molded large enough to allow for turning and also to compensate for shrinkage in drying.

The molded wheel is then trued and turned to the required form on a "potter's" wheel. This is a very simple device and consists principally of a revolving table and a horizontal cross-rail, along which the tool-slide is fed by hand. The wheel to be trued is not held in any way, but is simply placed on the center of the table, which is made of plaster-of-paris. The tool used for turning plain surfaces is a piece of flat unhardened steel. This can be fed either vertically or horizontally, and the graduated scales on the machine enable the operator to turn to the required dimension without taking any measurement.

The wheel is not reduced to the size finally required, an allowance being made for shrinking in the kiln, and also to provide for the final turning operations after burning. This allowance depends upon the size and grain of the wheel. A coarse wheel requires a greater allowance than a fine grain one, other conditions being equal. In the operation of the potter's wheel, hand tools are used to a certain extent, particularly in the formation of special shapes.

The next process in connection with vitrified grinding wheel manufacture is the burning of the wheels in order to partially melt the bond and form a solid but porous wheel. Much skill and care is required to burn wheels successfully, as the temperature must be very accurately controlled for a long period. The wheels to be burned are stacked in a brick kiln and are protected against the direct action of the flames and gases by packing them in fireclay saggers. When the kiln is full, the door is closed and luted with fireclay and the burning begins. This is continued without interruption for a period of from three to five days. The furnace is then allowed to cool slowly for a week.

When very hard close vitrified wheels are required, they are molded under hydraulic pressure. Very strong molds must be used, as the pressures are enormous. For example, a 36-inch wheel would require a pressure of about 1000 tons. The bond and grain for pressed wheels are first mixed dry in a tumbling barrel, after which water is added until the proper consistency is obtained. The mixture is then placed in a steel mold and pressed, after which the wheels are removed from the mold, dried and "fired" in the same manner as other vitrified wheels.

Still another method of molding vitrified wheels is known as the "tamped" process. The abrasive grains and clay for the bond are mixed together in a comparatively dry condition, and this mixture is then tamped into molds of the required size. After molding and drying, the wheels are burned in the kiln the same as wet mixed wheels. The tamped process is used principally for making small wheels.

A vitrified grinding wheel has the following qualities: it is very porous and therefore free cutting; it is not affected by water, oils, temperature or climatic conditions; the bond is hard and practically an abrasive itself. The wet-mixed vitrified process insures uniformity in the wheel, there being no hard or soft spots. The high temperature required for vitrified wheels burns out impurities, leaving nothing but the abrasive and its bond.

The disadvantages of the vitrified process are that it is slow; large wheels are likely to be cracked in the kiln; it is impracticable to produce wheels larger than about 34 inches in diameter and many manufacturers will not make wheels larger than 24 or 30 inches; the burning process is difficult to control perfectly, so that a given lot of wheels are likely to be somewhat off grade.

Vitrified wheels are extensively used for cylindrical grinding, for surface grinding when a disk form of wheel is used, for internal grinding, and for cutter grinding. They can readily be distinguished from other wheels by the reddish or reddish-brown color and the clear ringing sound produced when they are tapped.

The Silicate Process

In the silicate process, silicate of soda is the chief constituent used. The abrasive grains are first mixed with the bond in special machines, and the mixture is then tamped in a mold by hand. Some shapes of wheels are molded under hydraulic pressure, this method being used for disk and very hard wheels. After the wheels are molded, they are dried and baked in special ovens, from which all the fire gases are excluded. This causes a chemical reaction which hardens or sets the bond. The temperature of the oven is much lower than that required in the vitrified process. Silicate wheels can be made of large size and can be produced in a comparatively short time. Silicate wheels are made as large as 60 inches in diameter, and are especially adapted for grinding operations in which it is important to have the lowest possible wheel wear compatible with free cutting. One particular use of these wheels is for the grinding of large calender rolls used in paper mills. For this kind of work silicate wheels give excellent results, producing the desired "mirror" finish.

Elastic and Vulcanite Processes

Very thin wheels are made by the elastic or the vulcanite process. In the elastic process shellac is the principal ingredient in the bond, and the wheels are baked at a low temperature to set the shellac. Wheels made by this process are strong and have considerable elasticity, so that very thin wheels can be used with safety. Vulcanite wheels are bonded with vulcanized rubber. Very hard, tough, thin wheels can be made by this process, but they are rather expensive. Elastic and vulcanite wheels are made by a pressing or rolling operation, and have a very dense structure, the abrasive grains being embedded in the bonding material. This does not permit of as fast grinding as is possible with vitrified or silicate wheels.

Elastic and vulcanite wheels can safely be run in water, but elastic wheels should not be used in oil or caustic soda. The oil softens the bonding material so that the wheel wears down quickly, and the caustic soda causes disintegration of the wheel structure. This is not the case with vulcanite wheels, as they can be operated in both the liquids mentioned without injury to the bond or abrasive.

Elastic and vulcanite wheels are made as thin as 1/32 inch up to 4 inches in diameter, 1/16 inch up to 8 inches in diameter and 3/32 inch up to 12 inches in diameter. Wheels of very fine grain and of small diameter have been made as thin as 1/64 inch. Solid elastic wheels are being made commercially as large as 26 inches in diameter with a 2-inch face and vulcanite wheels 16 inches in diameter with a 2-inch face.

Thin wheels are used for slotting and cutting off stock, whereas thicker wheels are used for saw grinding, grinding between the teeth of gears, sharpening milling cutters, etc. They are also used on roll grinding for cutlery work where a very smooth polished surface is desired. For cutting off, a wheel speed of from 9000 to 11,000 feet surface speed has been found most efficient, but for most other operations a wheel speed of from 5000 to 6000 feet surface speed is recommended.

For general-purpose cutting-off wheels, where the speed of cutting is not a decided factor, vulcanite wheels seem to be the best. However, for cutting off tempered tool steel or alloy steel tools, where cool cutting is the main consideration, elastic wheels are the best, because of their softer grades and resulting cooler grinding action. While elastic and vulcanite wheels are being used for other operations, aside from slotting, grooving, nicking and cutting off, they are slowly being superseded by wheels manufactured by the vitrified process. The more porous structure of the vitrified wheels allows of a much freer and cooler grinding action with a proportionate increase in production.

Celluloid and Oil Processes

Grinding wheels made by the celluloid process have a bond of celluloid, as the name implies. The abrasive grains are mixed with the celluloid and this mixture is then rolled in sheets from which the wheels are cut. After seasoning for several months, the wheels are ready to finish. In the oil process, an oxidizing oil is mixed with the abrasive grains. This mixture is then formed into wheels by compressing it into molds in a hydraulic press. Oil-bonded wheels are similar in action to vulcanite wheels but are less dependable as to grade and uniformity. Celluloid and oil process wheels are only used to a very limited extent.

Selection of Wheels for Grinding

In selecting a grinding wheel, there are several factors to be considered. The grain and grade depend largely upon the area of contact between the wheel and work, the kind of material to be ground, the degree of hardness, etc. A harder wheel should be used on soft machine steel than on hardened tool steel. The reason for this will be best understood if we think of a grinding wheel as a cutter having attached to its periphery innumerable small teeth. When the wheel is of the proper grade, each small piece or cutting particle is held in place by the bond until it becomes too dull to cut effectively, when it is torn out by the increased friction. Obviously, these grains or cutters will become dull sooner when grinding hard than when grinding soft steel; hence, as a rule the harder the material the softer the wheel, and *vice versa;* although soft materials, such as brass, are ground with a soft wheel which crumbles easily, thus preventing the wheel from becoming loaded or clogged with metal, which would be the case if a hard-bond wheel were used.

When a hard wheel is used for grinding hard material the grit becomes dulled, but it is not dislodged as rapidly as it should be, with the result that the periphery of the wheel is worn smooth or glazed, so that grinding is impossible without excessive wheel pressure. Any undue pressure tends to distort the work, and this tendency is still further increased by the excessive heat generated. If the surface of the wheel becomes loaded with chips and burns the work, even when plenty of water is used, it is too hard. When too soft a wheel is used, the wear is, of course, greatly increased, as the particles of grit are dislodged too rapidly and consequently the wheel is always "sharp." This means that the abrasive has not done sufficient work to become even slightly dull, and the result is a rough surface on the work.

In regard to selecting the proper grinding wheel, as a general rule, materials of high tensile strength, such as soft and hardened steel, etc., require a wheel made from an aluminum-oxide abrasive; whereas, for grinding materials of low tensile strength, such as cast iron, brass, bronze, etc., a wheel made from a carbide of silicon abrasive should be used.

Arc of Contact a Deciding Factor in the Selection of Grinding Wheels

One of the many factors to consider in the selection of grinding wheels is the grading of the wheel with reference to the arc of contact that it makes with the work. Fig. 2 shows diagrammatically the principal conditions that must be met when selecting wheels from the standpoint of the arc of contact. These diagrams have been arranged in the order of the care necessary in selecting the proper grain and grade.

For grinding small cylindrical work, as shown at *A*, the conditions are almost ideal, because of the small arc of contact; the work and wheel are easily cooled, and, in addition, the dull abrasive grains readily fall out of the way and do not interfere with the grinding operation. An increase in the diameter of the work *b*, in relation to the wheel diameter, increases the arc of contact and may necessitate using a wheel of different grade. All other factors being equal, the larger the diameter of the work, the softer the grade of the wheel should be.

On surface grinding with a disk wheel, as shown at *B*, the conditions are not quite so satisfactory because, in this case, a greater portion of the wheel surface comes into contact with the work. When a narrow wheel of this shape is used and is fed across the work *c* a certain distance for each traverse of the table, very little difficulty is encountered if water or other cooling lubricants can be used. When the grinding must be done dry, however, considerable trouble is sometimes experienced due to heating and warping, especially when the work is thin; therefore wheels of a softer grade are used for grinding under the conditions shown at *B* than for grinding cylindrical parts as indicated at *A*.

For internal grinding, as shown at *C*, still more attention must be given to the grading of the wheel, because the arc of contact between the wheel and work *d* is much greater than in the other cases mentioned, and the difficulty of using a cooling lubricant is also increased. On small-hole work, wheels are usually specified to be of the same diameter as the hole or slightly larger, and then are trued until they just enter the hole. In such a case, the arc of contact is greatly increased, and the work and wheel tend to heat more rapidly; the difficulty of injecting a cooling lubricant into the hole is also increased. This makes it necessary to use a much softer wheel than if the wheel were smaller in relation to the diameter of the hole.

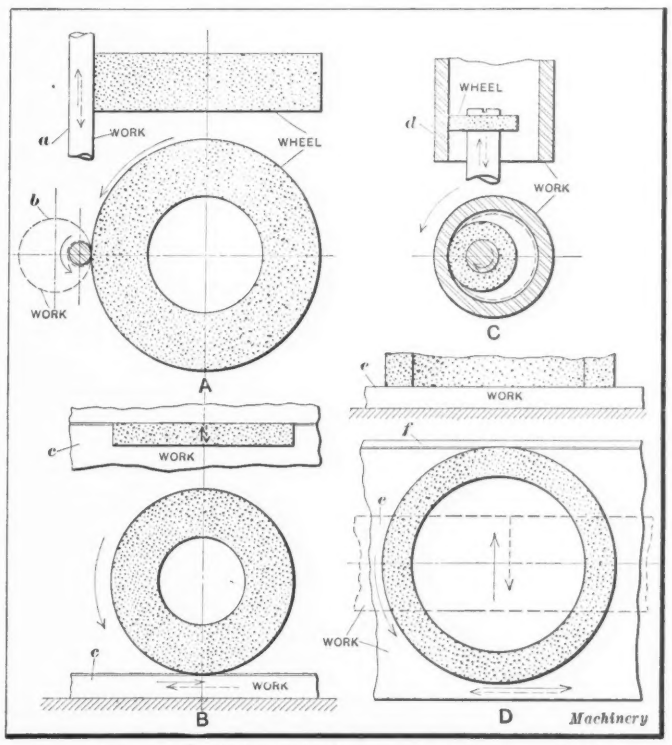


Fig. 2. Diagram illustrating Relation of Arc of Contact of Wheel to Work—A Deciding Factor in the Selection of Wheels

The most severe condition under which a grinding wheel operates and the one that requires the greatest attention in the selection of the proper grade and grain is that of surface grinding by the method illustrated at *D*. There are two conditions that must be taken into consideration. The first one is where the work *f* is wider than the diameter of the ring or cylinder wheel used. As the entire cutting face of the wheel is in contact with the work, a wheel of extremely soft bond and coarse grain should be used to secure satisfactory results; otherwise, the work will be heated to such an extent that it will spring out of shape and accurate results will be impossible. It is also necessary to have a copious supply of cooling liquid to reduce the heat.

The other condition is where the work *e* is less in width than the diameter of the wheel. In this case, the work has a tendency to tear the grains out of the bond; hence, a wheel of harder bond is required because of the chisel action of the edges of the work on the surface of the wheel. As the contact area is reduced, a wheel of finer grain and harder bond may be used.

Selecting Wheels for Plain Cylindrical Grinding

While it is impossible to give definite information regarding the selection of grinding wheels under all conditions, owing to the different factors which must be considered in each case, the wheels listed in the accompanying tables will enable one to obtain a general idea of the grades and grains that are commonly used for grinding different materials under ordinary conditions.

In the article on "Cylindrical Grinding" in the July number of MACHINERY, considerable space was devoted to the selection of wheels, and in order to amplify this data, the information given in Table II has been compiled. This table gives a list of wheels recommended by various wheel manufacturers, for grinding soft, hardened, and alloy steel, cast iron, brass, bronze and aluminum and can be used as a basis in making the proper selection. By referring to this table, it will be noticed that for grinding cast iron, cast brass, bronze, and aluminum, in most cases wheels made from carbide of silicon abrasives are recommended, although a few manufacturers recommend aluminum-oxide abrasives for this work. It will also be noticed that the bonding processes recommended by the various manufacturers differ to some extent.

For large-diameter cast-iron work, the Norton Co. recommends a grain 30, grade J, crystolon wheel, and for small-diameter cast iron, a grain 30, grade K, crystolon. The wheel for large diameters is one grade softer than that for comparatively small diameters. For bronze, a grain 30, grade K crystolon wheel has been used to advantage. When grinding armatures or other parts where copper and wrought iron pieces are arranged alternately, a Norton crystolon elastic wheel, grain 46, grade 2, has been used with success. For grinding chilled cast-iron rolls of large diameter, where it is desired to have a surface free from scratches, a crystolon wheel, grain 80, grade J has given good results. Of course it should be understood that this information is intended only as a general guide.

There are so many different alloys in use that it is difficult to specify any particular grain or grade of wheel that can be used satisfactorily on all of them. For instance, it is now necessary to distinguish between numerous kinds of brass of high and low zinc content, such as "red" and "yellow" brass, bronze, naval brass, and many others. The term "bronze" was formerly employed to indicate an alloy whose chief constituents were copper and tin-copper—but in recent years many different alloys are referred to as bronzes.

Commercial brass is generally understood to mean an alloy of two-thirds copper and one-third zinc, but this varies. The copper content may vary from 60 per cent to 80 per cent; likewise the amount of copper and tin in bronze also varies considerably. With but two exceptions alloys of zinc, tin, lead, iron, manganese, and nickel with copper require no change in the grade and grain of the grinding wheel. The exceptions are nickel-bronze and bell metal—two of the hardest alloys. These can be ground with success by the same wheel as the other alloys, but where a large number of pieces are to be ground a different wheel should be selected. For nickel-bronze a wheel made of crystolon, grain 24, grade Q,

gives good results. For bell metal, a wheel of the same material but of a little harder grade is recommended, such as grade R and grain 24 or 30. Comparatively thin wheels are often used for such metals, and the work is ground by what is known as the "fixed wheel" method. Careful experiments made in grinding brasses and bronzes with a crystolon wheel, showed that a grain 30, grade P wheel gave the best results.

Wheels for Form-grinding

In form-grinding, the wheel is fed straight in on the work without being traversed and therefore is required to take both a roughing and a finishing cut. Usually pieces that are form-ground—crankshafts not included—are finished right from the rough-turning to the final grinding in one straight-in cut. It is not uncommon, therefore, to find that the wheels generally recommended for form-grinding are of a combination grain. Table III gives the grain and grade of wheels for form-grinding, as recommended by various grinding wheel manufacturers. The conditions that govern the grain and grade of the wheel for form-grinding are: the width of the face of the wheel in contact with the work, the rigidity of the machine in which the wheel is held, and the speed at which the work is rotated. For average work a combination grain, grade M or N wheel is recommended. These grades have been found to give good results on 0.20 to 0.50 carbon steel, not hardened, as well as chrome-nickel or chrome-vanadium steel heat-treated.

Wheels for Internal Grinding

The selection of the proper grain and grade of wheel for internal grinding is one that cannot be easily decided upon. The grain and grade to use on any given job depends not only upon the kind of work and the work and wheel speeds, but also very largely upon the stiffness of the machine and the firmness with which the wheel-spindle is supported. Briefly summarized, some of the points to take into consideration are: diameter of hole; speed of wheel-spindle; kind of work; whether the hole is plain or keyseated; nature of material; stiffness of machine; rigidity of wheel-spindle; method of holding grinding wheel; and character of operation—whether cut is for roughing or finishing.

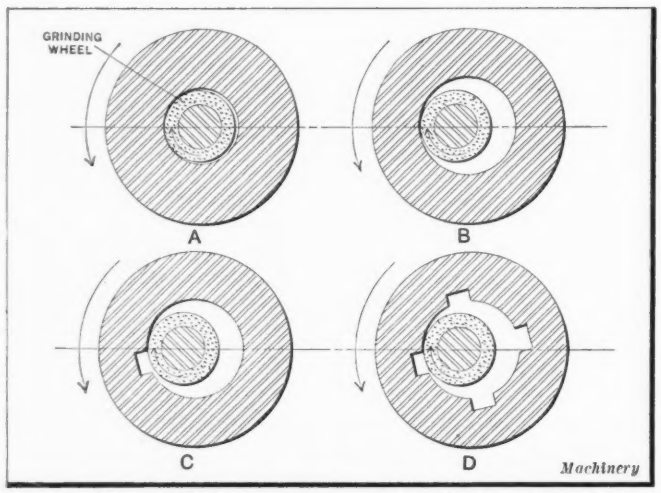


Fig. 3. Diagram illustrating Cases governing Selection of Wheels for Internal Grinding

As regards the diameter of the hole, there are several points to consider. In the first place, where the hole is below ¾ or 1 inch diameter, for economical reasons, it is necessary to have the wheel as large as possible; the wheel is usually ordered of the same diameter or larger than the hole to be ground and is then trued until it enters the hole. By using a wheel of practically the same size as the hole, as shown at *A* in Fig. 3, the arc of contact of wheel and work is large and, consequently, a much softer bond wheel must be used than if the wheel were small in relation to the diameter of the hole. Where the wheel is small, in proportion to the diameter of the hole, a harder bond and finer grain wheel can be used.

The speed at which a wheel should be operated for internal grinding is not always an easy matter to determine. In the first place, if the wheel is very small a high peripheral speed is necessary, and difficulty is experienced in obtaining a

TABLE II. GRAIN AND GRADE OF GRINDING WHEELS FOR PLAIN CYLINDRICAL GRINDING

Wheel Manufacturers	Abrasive (All Wheels Bonded by Vitrified Process)	0.20 to 0.50 Per Cent Carbon Steel (Soft)		0.20 to 0.50 Per Cent Carbon Steel (Hardened)		Chrome-nickel or Chrome-vanadium (Heat-treated)	
		Grain	Grade	Grain	Grade	Grain	Grade
Abrasive Material Co.	Boro-carbone	24 to 46 Comb.	L to M	24 to 46 Comb.	K	24 to 46 Comb.	M to N
American Emery Wheel Works.	Corundum	58—24 Comb.	L to M	46 to 60	K	58—24 Comb.	L
Carborundum Co.	Aloxite	36	M to O	36	P	40	J
Cortland Corundum Wheel Co.	Oxaluma	36	M to N	38 to 46	K to L	24 to 36	M
Detroit Grinding Wheel Co.	Corundum	46	M to N	46	O to P	24 to 36	M to O
Norton Co.	Alundum	38—36 Comb.	L	46	K	38—24 Comb.	L
Safety Emery Wheel Co.	Rex	30 to 36	M to P	30 to 36	M to P	24 to 36	M to P
Sterling Grinding Wheel Co.	Corundum	20 to 36	2 to 2½	36	2	20 to 30	2½ to 3
Vitrified Wheel Co	Corundum	24 to 36	D^2 to D^3	36 to 40	E^1 to E^2	24 to 30	D^3 to E^1
Waltham Emery Wheel Co.	Alowalt	30 Comb.	3¼ to 3¾	....	... .	30 Comb.	3¼ to 3¾
Waltham Emery Wheel Co.	Corowalt	.....	.....	50	2¾	....•...	.....

Wheel Manufacturers	Abrasive (Vitrified Bond except where marked under grade)	Cast Iron		Cast Brass and Bronze		Cast Aluminum	
		Grain	Grade	Grain	Grade	Grain	Grade
Abrasive Material Co.	Carbide of Silicon	30 to 60	K to M	30 to 46	L to N	30 to 36	2E to 3E†
American Emery Wheel Works.	Carbolite	36 to 54	K to M	.....	.....	46 to 60	2E to 2½E†
American Emery Wheel Works.	Corundum	.....	.....	24	M to N	.....	.....
Carborundum Co.	Carborundum	24 to 60	L to N	24 to 36	L to M	16 to 24	2†
Cortland Corundum Wheel Co.	Carborundum	16 to 30	L to M	.....	.....	. ....	. ....
Cortland Corundum Wheel Co.	Oxaluma	.....	.....	20 to 36	M to O	16 to 30	N to R
Detroit Grinding Wheel Co.	Carborundum	16 to 36	G to 5*	36 to 46	N to P*	20 to 36	J to K*
Norton Co.	Crystolon	30	J to K	30	K to L	36	4†
Safety Emery Wheel Co.	Corex	24 to 36	M½ to P½	20 to 30	P½ to I½	30 to 36	M½ to P½
Sterling Grinding Wheel Co.	Corundum	20	2 to 3	30	3	30 to 36	3 to 3½
Vitrified Wheel Co	Carbolon	24 to 46	D_2 to E_1	.....	.....	36	4½†
Waltham Emery Wheel Co.	Corundum	.....	....	24 to 30	E_3	.....	.....
Waltham Emery Wheel Co.	Carbowalt	24 to 46	2¾ to 3½	30 to 46	2¾ to 3½	30 to 46	2½ to 3†

Machinery

• Grinding wheel bonded by silicate process.
† Grinding wheel bonded by elastic process.
Note: The numbers 38 and 58 preceding, in some cases, the grain sizes, indicate a special manufacturing process for the abrasive listed.

TABLE III. GRAIN AND GRADE OF GRINDING WHEELS FOR EXTERNAL FORM GRINDING

Wheel Manufacturers	Abrasive (Vitrified Bond except where marked under grade)	0.20 to 0.50 Per Cent Carbon Steel (Soft)		0.20 to 0.50 Per Cent Carbon Steel (Hardened)		Chrome-nickel or Chrome-vanadium Steel (Heat-treated)	
		Grain	Grade	Grain	Grade	Grain	Grade
Abrasive Material Co.....	Boro-carbone	24 Comb.	L to M	24 Comb.	J to K	24 Comb.	L to M
American Emery Wheel Works.	Corundum	58-24 Comb.	L to M	46 to 60	K to L	58-36 to 58-60	J to L
Carborundum Co.	Aloxite	24 to 30	J to K	24 to 30	M	24 to 30	J to K
Cortland Corundum Wheel Co..	Oxaluma	24 to 54	L to M	24 to 60	K to L	30 to 46	K to M
Detroit Grinding Wheel Co....	Carbo-alumina	36 to 46	M to P*	36 to 46	L to O*	36 to 46	M to O*
Norton Co.	Alundum	24 Comb. or 46	L to N	20 Comb. or 46	L to N	24 Comb. or 46	J to M
Safety Emery Wheel Co.....	Rex	24 to 60	M½ to P½	24 to 60	M to P	24 to 60	M to P
Sterling Grinding Wheel Co....	Corundum	20 to 36	2 to 2½	20 to 30	2	16 to 20	3½
Vitrified Wheel Co.....	Corundum	46	E	36 to 54	D_2	36 to 46	D_3 to E
Waltham Emery Wheel Co.....	Alowalt	46	3 to 3½	50	2¾ to 3¼	46 to 60	3 to 3½

Machinery

* Grinding wheel bonded by silicate process.
Note: The number 58 preceding, in some cases, the grain sizes indicates a special manufacturing process for the abrasive listed.

bearing for the spindle that will stand up to the speed at which the grinding wheel would give the best efficiency. The lower the wheel speed, the harder the bond should be, other conditions remaining the same.

When a smooth hole is plain, as shown at *B*, Fig. 3, a softer wheel should be used than when the hole is keyseated, as shown at *C* and *D*. Slots or keyseats have a chisel action on the wheel face and quickly tear out the grains; hence for keyseated work a harder wheel should be used than on plain-hole work, and it should also have a wider face.

The nature of the material to be ground is also a determining factor in the selection of the grade and grain of the wheel, as well as the abrasive. For grinding soft steel varying from 0.20 to 0.30 per cent carbon content, the bond should be harder than for grinding the same steel in its hardened condition. Hardened steel has a tendency to glaze the wheel much more rapidly than soft work, and glazing is one of the greatest difficulties met with in grinding. Wheels made from aluminum-oxide abrasives give excellent service on steel. For grinding cast iron, carbide of silicon abrasives are more satisfactory; the latter can also be used on brasses and bronzes, aluminum, nickel-bronze and government bronze.

The rigidity of a machine has about as much to do with the selection of the grade and grain of the wheel as any other one factor. The fact is often overlooked that a machine which is not rigid should use a harder bond wheel than one which is. The greater the rigidity of the machine, the softer the grade and the coarser the grain of the wheel should be. Of course the rigid machine also has the advantage of being able to remove the stock with rapidity and without chatter marks.

For rough internal grinding it is generally advisable to use a wheel of coarse grain and soft bond, because of the greater cutting capacity of the wheel; under average conditions, a wheel of finer grain and harder bond would be better for finishing. In commercial grinding, however, the time necessary to change the wheels for roughing and finishing would

TABLE IV. GRAIN AND GRADE OF GRINDING WHEELS FOR INTERNAL GRINDING

Wheel Manufacturers	Abrasive (Vitrified Bond except where marked under grade)	0.20 to 0.50 Per Cent Carbon Steel (Soft)		0.20 to 0.50 Per Cent Carbon Steel (Hardened)		Chrome-nickel or Chrome-vanadium Steel (Heat-treated)	
		Grain	Grade	Grain	Grade	Grain	Grade
Abrasive Material Co.....	Boro-carbone	46 to 60	L to M	46 to 60	J to K	46 to 60	J to L
American Emery Wheel Works.	Corundum	34 to 46	K to L	46 to 60	J to K	58-46	J to K
Carborundum Co.	Aloxite	50	M to N	60	M to N	50	M to N
Cortland Corundum Wheel Co..	Oxaluma	46 to 50	J to K	46 to 60	J to K	46 to 50	K to L
Detroit Grinding Wheel Co....	Carbo-alumina	46	L to N*	60	J to L*	46	I to K*
Norton Co.	Alundum	38-46	J to M	38-46	J to L	38-46	J to K
Safety Emery Wheel Co.....	Rex	46	M to P	60	M to P	46	M to P
Vitrified Wheel Co.....	Corundum	46	D_2 to D_3	60	D_2 to D_3	46	D_3
Waltham Emery Wheel Co.....	Alowalt	46 to 60	2½ to 3	46 to 60	2½ to 3	46 to 60	2½ to 3

Wheel Manufacturers	Abrasive (Vitrified Bond except where marked under grade)	Cast Iron		Cast Brass and Bronze		Cast Aluminum	
		Grain	Grade	Grain	Grade	Grain	Grade
Abrasive Material Co.....	Carbide of Silicon	46 to 60	K to M	46 to 60	L to M	46 to 60	2E to 3E†
American Emery Wheel Works.	Carbolite	46 to 60	J to L	.....	.....	46 to 60	1½E to 2E†
American Emery Wheel Works.	Carbolite or Corundum	.....	.....	46 to 60	K	.....	.....
Carborundum Co.	Carborundum	36 to 40	P to S	40 to 50	M to P	50	P to R
Cortland Corundum Wheel Co..	Carborundum	30 to 46	K	.....	.....	.....	.....
Cortland Corundum Wheel Co..	Oxaluma	.....	.....	46 to 60	L to M	36 to 54	M to N
Detroit Grinding Wheel Co....	Carborundum	36 to 46	K to M*	36 to 46	J to L*	24 to 36	H to K*
Norton Co.	Crystolon	30 to 46	I to L	30 to 46	K to M	36	2 to 3†
Safety Emery Wheel Co.....	Corex	36 to 60	M to M¾	36 to 60	M to M½	36 to 60	M to M¾
Vitrified Wheel Co.....	Carbolon	36	D_2	.....	.....	46	4†
Vitrified Wheel Co.....	Corundum	.....	.....	46	D_3	.....	.....
Waltham Emery Wheel Co.....	Carbowalt	30 to 46	2 to 3	.....	.....	30 to 46	1¾ to 2†
Waltham Emery Wheel Co.....	Alowalt	.....	.....	50	2½ to 2¾	.....	.....

Machinery

* Grinding wheels bonded by silicate process.
† Grinding wheels bonded by elastic process.
Note: The numbers 38 and 58 preceding, in some cases, the grain sizes, indicate a special manufacturing process for the abrasive listed.

TABLE V. GRAIN AND GRADE OF GRINDING WHEELS FOR SURFACE GRINDING

Wheel Manufacturers	Abrasive (Vitrified Bond except where marked under grade)	0.20 to 0.50 Per Cent Carbon Steel (Soft)		0.20 to 0.50 Per Cent Carbon Steel (Hardened)		Chrome-nickel or Chrome-vanadium Steel (Heat-treated)	
		Grain	Grade	Grain	Grade	Grain	Grade
Grinding Wheels of Disk Type							
Abrasive Material Co.	Boro-carbone	24 Comb.	L to M	24 Comb.	J to K	24 Comb.	L to M
American Emery Wheel Works.	Corundum	30 to 46	J to K	36 to 46	I to J	58-30 to 58-46	I to J
Carborundum Co.	Aloxite	24	N to P	30	R to S	30	R to S
Cortland Corundum Wheel Co.	Oxaluma	24 to 30	K to L	24 to 30	K	30 to 46	J to K
Detroit Grinding Wheel Co.	Carbo-alumina	16 to 46	E to M*	24 to 46	E to G*	24 to 46	E to H*
Norton Co.	Alundum	14 to 24	J to K	14 to 30	H to K†	14 to 30	H to K†
Safety Emery Wheel Co.	Rex	30 to 60	M to P	36 to 46	M to P	36 to 46	M to P
Vitrified Wheel Co.	Corundum	36 to 46	E	46 to 60	D_3 to E	36	E
Waltham Emery Wheel Co.	Alowalt	36 to 46	2½ to 3	36 to 46	2 to 2¾	36 to 46	2 to 3
Grinding Wheels of Ring Type							
Abrasive Material Co.	Boro-carbone	24	J*	20 to 30	G to I*	24	J*
American Emery Wheel Works.	Corundum	58-20 to 58-30	¾ to 1½*	24 to 36	½ to 1*	58-20 to 58-30	½ to 1*
Carborundum Co.	Aloxite	24	N to P	30	R to S	30	R to S
Cortland Corundum Wheel Co.	Oxaluma	24 to 30	K to L	24 to 30	K	30 to 46	J to K
Detroit Grinding Wheel Co.	Carbo-alumina	16 to 24	E to G*	24 to 46	E to G*	24 to 46	E to H*
Norton Co.	Alundum	14 to 36	I to K†	14 to 36	G to K†	14 to 36	G to K†
Safety Emery Wheel Co.	Rex	24 to 46	M to M¾	36 to 46	M to P	36 to 46	M to P
Vitrified Wheel Co.	Corundum	36	D_2	36 to 46	D_2	36	D_2
Waltham Emery Wheel Co.	Alowalt	36 to 46	2½ to 3	36 to 46	2 to 2¾	36 to 46	2 to 3

Machinery

* Grinding wheels bonded by silicate process.
† Vitrified or silicate bond.
Note: The number 58 preceding, in some cases, the grain sizes indicates a special manufacturing process for the abrasive listed.

more than overbalance the gain made by using a wheel best suited for both purposes, so that a wheel is generally selected which will be fairly suitable for both roughing and finishing. When a good finish is desired, it is the general practice to dress the wheel, after taking the roughing cut, by passing a diamond slowly across the face.

In Table IV are given the grade and grain selections of grinding wheels for the internal grinding of soft, hardened

TABLE VI. GRAIN AND GRADE OF GRINDING WHEELS FOR SURFACE GRINDING

Wheel Manufacturers	Abrasive	Bonding Process	Cast Iron		Cast Brass and Bronze	
			Grain	Grade	Grain	Grade
Grinding Wheels of Disk Type						
Abrasive Material Co.	Carbide of Silicon	Vitrified	30 to 46	L to M	30 to 46	K to L
American Emery Wheel Works.	Carbolite	Vitrified	36 to 46	K to L	36 to 60	K to L
Carborundum Co.	Carborundum	Vitrified	24	P to S	30	P to S
Cortland Corundum Wheel Co.	Carborundum	Vitrified	20 to 30	L to M	.....	.....
Cortland Corundum Wheel Co.	Oxaluma	Vitrified	.....	.....	20 to 24	K to M
Detroit Grinding Wheel Co.	Carbo-alumina	Silicate	16 to 36	D to H	24 to 46	F to H
Norton Co.	Crystolon	Vitrified or Silicate	20 to 30	I to K	.....	.....
Norton Co.	Crystolon	Vitrified	.....	.....	20 to 30	I to K
Safety Emery Wheel Co.	Corex	Vitrified	20 to 26	M½ to P½	30 to 36	M½ to P
Vitrified Wheel Co.	Carbolon	Vitrified	20 to 36	E_3 to E	.....	.....
Vitrified Wheel Co.	Corundum	Vitrified	.....	.....	24 to 36	E_3 to E
Waltham Emery Wheel Co.	Carbowalt	Vitrified	24 to 36	2 to 3	.....	.....
Waltham Emery Wheel Co.	Carbowalt	Three Processes	.....	.....	24 to 36	2 to 3

Wheel Manufacturers	Abrasive	Bonding Process	Cast Aluminum		Malleable Iron Castings	
			Grain	Grade	Grain	Grade
Abrasive Material Co.	Carbide of Silicon	Elastic	30 to 36	2E to 3E	.....	.....
Abrasive Material Co.	Boro-carbone	Vitrified	.....	.....	24 Comb.	M
American Emery Wheel Works.	Carbolite	Elastic	36 to 60	1½E to 2E	.....	.....
American Emery Wheel Works.	Carbolite	Vitrified	.....	.....	30 to 36	K to L
Carborundum Co.	Carborundum	Elastic	36	5 to 6	.....	.....
Carborundum Co.	Aloxite	Vitrified	.....	.....	16 to 24	G to H
Cortland Corundum Wheel Co.	Oxaluma	Vitrified	20 to 24	K to M	14 to 20	Q to R
Detroit Grinding Wheel Co.	Carbo-alumina	Silicate	20 to 36	I_1 to M_1	16 to 30	F to H
Norton Co.	Crystolon	Elastic	24 to 46	1½ to 2½	.....	.....
Norton Co.	Alundum	Vitrified	.....	.....	14 to 36	I to K*
Safety Emery Wheel Co.	Corex	Vitrified	36 to 46	M to P	.....	.....
Safety Emery Wheel Co.	Rex	Vitrified	.....	.....	36 to 60	M½ to P
Vitrified Wheel Co.	Carbolon	Elastic	20 to 36	4½	.....	.....
Vitrified Wheel Co.	Corundum	Vitrified	.....	.....	16 to 30	E_1 to E_3
Waltham Emery Wheel Co.	Carbowalt	Elastic	24 to 36	1¾ to 2	.....	.....
Waltham Emery Wheel Co.	Alowalt	Vitrified	.....	.....	24 to 36	2½ to 3

Machinery

* For rough castings, unannealed, use crystolon, vitrified, grain 20 to 30, grade J to M.

TABLE VII. GRADE AND GRAIN OF GRINDING WHEELS FOR SURFACE GRINDING

Grinding Wheels of Ring Type

Wheel Manufacturers	Abrasive	Bonding Process	Cast Iron		Cast Brass and Bronze	
			Grain	Grade	Grain	Grade
Abrasive Material Co.	Carbide of Silicon	Vitrified	24-30	I to J	20 to 30	I to J
American Emery Wheel Works.	Carbolite	Vitrified	16-24	I to K	20 to 30	I to K
Carborundum Co.	Carborundum	Vitrified	24	P to S	30	P to S
Cortland Corundum Wheel Co.	Carborundum	Vitrified	20 to 30	L to M	.....	.....
Cortland Corundum Wheel Co.	Oxaluma	Vitrified	.....	.....	20 to 24	K to M
Detroit Grinding Wheel Co.	Carbo-alumina	Silicate	16 to 24	E to G	16 to 36	G to K
Norton Co.	Crystolon	Vitrified or Silicate	14 to 30	I to K	.....	.....
Norton Co.	Crystolon	Vitrified	.....	.....	14 to 30	I to L
Safety Emery Wheel Co.	Corex	Vitrified	20 to 36	M½ to P½	30 to 36	M½ to P
Vitrified Wheel Co.	Carbolon	Vitrified	30	E_2	.....	.....
Vitrified Wheel Co.	Corundum	Vitrified	.....	.....	30	E_2
Waltham Emery Wheel Co.	Carbowalt	Vitrified	24 to 36	2 to 3	.....	.....
Waltham Emery Wheel Co.	Carbowalt	Three Processes	.....	.....	24 to 36	2 to 3

Wheel Manufacturers	Abrasive	Bonding Process	Cast Aluminum		Malleable Iron Castings	
			Grain	Grade	Grain	Grade
Abrasive Material Co.	Carbide of Silicon	Elastic	24 to 30	¾E to 1E	.....	.....
Abrasive Material Co.	Boro-carbone	Silicate	.....	.....	20 to 24	J
American Emery Wheel Works.	Carbolite	Vitrified	20 to 30	I to K	14 to 24	I to K
Carborundum Co.	Carborundum	Elastic	36	5 to 6	.....	.....
Carborundum Co.	Aloxite	Vitrified	.....	.....	16 to 24	G to H
Cortland Corundum Wheel Co.	Oxaluma	Vitrified	20 to 24	K to M	14 to 20	Q to R
Detroit Grinding Wheel Co.	Carbo-alumina	Silicate	20 to 36	H to K	16 to 30	E to G
Norton Co.	Crystolon	Vitrified	16 to 30	H to K	.....	.....
Norton Co.	Alundum	Vitrified or Silicate	.....	.....	14 to 30	H to L*
Safety Emery Wheel Co.	Corex	Vitrified	36 to 46	M to P	.....	.....
Safety Emery Wheel Co.	Rex	Vitrified	.....	.....	36 to 60	M½ to P
Vitrified Wheel Co.	Carbolon	Elastic	20 to 36	4	.....	.....
Vitrified Wheel Co.	Corundum	Vitrified	.....	.....	24	E_1
Waltham Emery Wheel Co.	Carbowalt	Elastic	24 to 36	1¾ to 2	.....	.....
Waltham Emery Wheel Co.	Alowalt	Vitrified	.....	.....	24 to 36	2 to 3

Machinery

* For rough castings, unannealed, use crystolon, grain 16 to 24, grade J to M.

and alloy steels, and cast iron, brass, bronze, and aluminum. These gradings are supplied by the various grinding wheel manufacturers, and as will be noticed, cover a considerable range.

Wheels for Surface Grinding

There are several conditions in surface grinding which govern to a marked extent, the grain and grade of wheel to use. For instance, the arc of contact of a ring type wheel with the work is much greater than it is on disk wheels used for either cylindrical or internal grinding. In surface grinding there are three chief conditions: first, where a disk wheel is used, as shown at *B* in Fig. 2; second where a ring or cylinder wheel is used on work wider than the wheel diameter; and third where the work is less in width than the diameter of the wheel, as shown at *D* in the same illustration. In Tables V, VI and VII are given the wheel selections for surface grinding different materials with the disk type and ring or cylinder types of grinding wheels.

Some of the other conditions which govern the selection of wheels for surface grinding are: materials to be ground, degree of accuracy required, quality of finish, and shape and size of work. For grinding with disk wheels used on the planer type of surface grinding machines, the grain commonly used varies from 46 to 60, whereas the grade is about H for hardened steel, when using wheels made from aluminum-oxide abrasives. For hardened high-speed steel or very thin pieces of hardened carbon steel, the bond of the wheel should be about grade G, the same grain being used. For grinding cast iron, wheels made from carbide of silicon abrasives are employed, the grain being about 36, and the grade J.

When grinding with cylinder or ring wheels, the greatest trouble is to get rid of the chips and prevent heating of the work. The grinding of a continuous flat surface with a ring wheel makes it necessary to employ a rapid work speed and shallow cuts, using wheels of relatively coarse grain and soft bond. This is necessary so as to make very small chips which will not fill the spaces between the cutting points on the wheel. When the work is narrow in proportion to the diameter of the wheel, as shown at *D* in Fig. 2, there is less trouble with chips. For surface grinding work with ring wheels, the Norton Co. recommends the grades and grains as follows: cast iron, grade I; chilled cast iron, grade I or J; hardened steel, grade G or H; high-speed steel, grade I; nickel-bronze, grade Q or P; government bronze, grain 24, grade Q to grain 36, grade P.

For surface grinding unannealed rough malleable iron castings, the Norton Co. recommends a crystolon, vitrified wheel, grain 20 to 30, grade J to N for disk wheels, and grain 16 to 24, grade J to M for ring or cylinder wheels. For annealed malleable iron castings that are fairly smooth, the Norton Co. recommends an alundum wheel, vitrified process, grain 14 to 36, grade I to K for disk wheels, and alundum, vitrified or silicate, grain 14 to 30, grade H to L for ring or cylinder wheels. This same information applies to all other listings given in Tables VI and VII.

The wheels used on Blanchard vertical surface grinders are of the cylinder type, 16 inches in diameter, 5 inches high, and of widths of rims varying from 1¼ to 1½ inch. All wheels used on Blanchard surface grinders are wire wound by the maker. In selecting wheels for this machine, the two most important factors to consider are the material to be ground and the area presented to the wheel. For grinding cast iron, aluminum, brass, and alloys of low tensile strength, wheels made from carbide of silicon abrasives, and having a vitrified bond have given the best results. For steel, either hard or soft, and for the tougher and stronger bronzes, wheels made from aluminum oxide abrasives and bonded by the silicate process are used. As a general rule, hard-bond wheels should be used on soft tough stock, and soft-bond wheels on hardened stock.

The area to be considered in grinding on a surface grinder

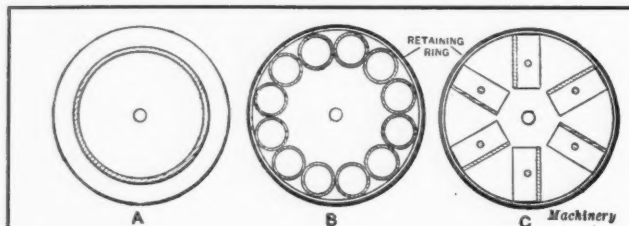
of the rotary table vertical spindle type is that presented to the wheel by a group of pieces held on the chuck at one time. These have been divided into three classes, *viz.*, those of narrow, medium, and broad surfaces. The wheels recommended by the Blanchard Machine Co. for these various classes of work are given in Tables VIII, IX, and X, respectively. These tables will serve as a general guide in selecting the wheels, but cannot be expected in all cases to give the best wheel for every job. The wheels listed are those made by the American Emery Wheel Works and the Norton Co. The reason for this is that a large number of tests have been made with these particular wheels, on the work specified.

The illustration shown in connection with Table VIII is given to indicate "narrow" surfaces. At *A* is shown a ring with a ¾-inch rim. At *B* is shown a group of rings with walls ¼ inch wide, whereas at *C* are shown castings having ribs ½ inch wide and small bosses that must be ground. These are shown to indicate in a general way what is meant by "narrow surfaces".

The illustration accompanying Table IX shows examples of work to indicate medium surfaces. Ring-shaped parts like the one shown at *A* may vary in width from 2 to 3 inches; the parts shown at *B* are washers 3½ inches in diameter with a 2-inch hole, leaving a wall of ¾ inch. Thirty-four pieces are held on the table. If a single instead of a double row of pieces was held on the chuck at one time, this class of work would be considered as having narrow surfaces. The castings shown at *C* have a ground surface about 1¼ inch wide, and sixteen pieces are held on the table.

TABLE VIII. WHEELS FOR GRINDING NARROW SURFACES ON VERTICAL SURFACE GRINDER *

Illustration indicates General Class of Work for which the Wheels listed are adapted



Material	Abrasive	Bonding Process	Width of Wheel Rim	Grain	Grade
Cast Iron†	Carbolite	Vitrified	1¼	30	I
	Carbolite	Vitrified	1½	24	I
	Crystolon	Vitrified	1¼	30	I
	Crystolon	Vitrified	1½	24	J
Chilled Cast Iron	Carborundum	Vitrified	1½	20	I
Soft Steel	Corundum	Silicate	1¼	58–30	I
	Alundum	Silicate	1¼	38–30	I
	Alundum	Silicate	1¼	38–30	J
Hardened Steel	Corundum	Silicate	1¼	30‡	¾
	Alundum	Silicate	1¼	38–30	H
Aluminum	Alundum	Vitrified	1½	38–14	I

Machinery

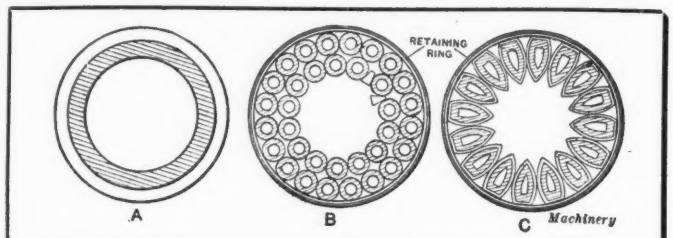
* Recommended by the Blanchard Machine Co.
† For brass, bronze, and similar alloys of low tensile strength, use same wheels as for cast iron. For hard bronze use same wheels as for soft steel.
‡ No. 46 grain and same grade is also used on narrow surfaces to obtain a smoother finish.
Note: The numbers 38 and 58 preceding, in some cases, the grain sizes indicate a special manufacturing process for the abrasive listed.

Summary—Points on the Selection of Grinding Wheels

The following are the most important conditions governing the selection of grinding wheels: Speed of wheel and work, size and shape of piece ground, composition and temper of metal, design and condition of machine, rigidity of floor, wet or dry grinding, quality of finish wanted, amount of stock to be removed, etc. Usually a wheel should be selected that is nearly the same as that found on previous jobs to give satisfaction, and then watched carefully under working conditions to see what the cutting action is. The following are a few of the most important points to be considered in making a selection of the correct grain and grade of wheel to use:

TABLE IX. WHEELS FOR GRINDING MEDIUM SURFACES ON VERTICAL SURFACE GRINDER *

Illustration indicates General Class of Work for which the Wheels listed are adapted



Material	Abrasive	Bonding Process	Width of Wheel Rim	Grain	Grade
Cast Iron†	Carbolite	Vitrified	1½	20	H
	Carbolite	Vitrified	1½	14	I
	Crystolon	Vitrified	1½	20	H
	Crystolon	Vitrified	1½	14	I
Chilled Cast Iron	Carbolite	Vitrified	1½	20	H
Soft Steel	Corundum	Silicate	1½	58–24	1
	Alundum	Silicate	1½	38–24	H
Hardened Steel	Corundum	Silicate	1¼	30	½
	Alundum	Silicate	1¼	38–24	H
High-speed Steel	Corundum	Silicate	1½	58–24	¾
Aluminum	Alundum	Vitrified	1½	38–14	I
Fiber	Alundum	Silicate	1½	38–24	G

Machinery

* Recommended by the Blanchard Machine Co.
† For brass, bronze, and similar alloys of low tensile strength, use same wheels as for cast iron. For hard bronze use same wheels as for soft steel.
Note: The numbers 38 and 58 preceding, in some cases, the grain sizes, indicate a special manufacturing process for the abrasive listed.

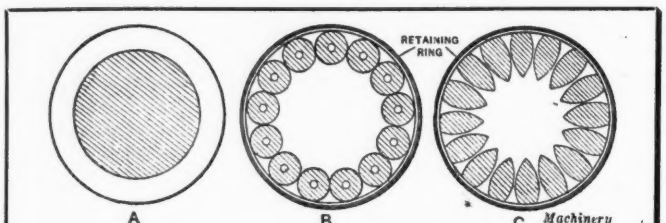
1. For materials of low tensile strength, use grinding wheels made from the carbide of silicon abrasives. For materials of high tensile strength, use grinding wheels made from aluminum-oxide abrasives.

2. If a wheel glazes over, fills, and cuts slowly, it is too hard—try one or two grades softer.

3. If a wheel wears away too fast, wears out of round or quickly loses its shape, it is too soft. Users often think that

TABLE X. WHEELS FOR GRINDING BROAD SURFACES ON VERTICAL SURFACE GRINDER *

Illustration indicates General Class of Work for which the Wheels listed are adapted



Material	Abrasive	Bonding Process	Width of Wheel Rim	Grain	Grade
Cast Iron†	Carbolite	Vitrified	1½	14	H
	Crystolon	Vitrified	1½	24	G
Soft Steel	Corundum	Silicate	1½	58–14	⅜
	Alundum	Silicate	1½	38–14	I
	Alundum	Vitrified‡	1½	38–14	I
Hardened Steel	Corundum	Silicate	1¼	24	⅝
	Alundum	Silicate	1¼	38–24	G
High-speed Steel	Corundum	Silicate	1½	58–24	⅝

Machinery

* Recommended by the Blanchard Machine Co.
† For brass, bronze, and similar alloys of low tensile strength, use same wheels as for cast iron. For hard bronze use same wheels as for soft steel.
‡ Wheels made by vitrified process are used only for roughing purposes.
Note: The numbers 38 and 58 preceding, in some cases, the grain sizes, indicate a special manufacturing process for the abrasive listed.

because a wheel wears out of round, it has "soft spots", but this is a mistake. It is a sure indication that a harder grade or higher wheel speed is necessary.

4. Increasing the speed of a wheel will make it act like a wheel of harder grade; and decreasing the speed will make it appear softer. A wheel should be speeded up as the diameter is reduced by wear, in order to maintain the proper surface speed.

5. The greater the surface contact between the wheel and the work, the softer the grade of the wheel should be. Thus a ring, cylinder or cup-wheel should be softer than a disk wheel for grinding the same material, and a very thin disk wheel should be harder than a thick one.

6. In cylindrical grinding, work of large diameter will require a softer wheel than work of small diameter. Pieces which have a narrow surface or edge to be ground need a harder wheel than wide surfaces.

7. In cylindrical grinding, increasing the work speed tends to wear away the wheel faster. Vibration due to worn bearings, lack of rigidity in the machine, or a shaky floor, has the same effect. With any of these conditions, a harder wheel should be used.

8. The use of water permits a wheel of slightly harder bond to be used and improves the finish of the work. It also prevents overheating of the work and the resulting distortion.

9. A wheel is the most efficient when it is just soft enough to cut freely without excessive wear, and not hard enough to cause glazing.

10. To preserve some special shape of face, a relatively hard wheel should be used—generally a wheel of combination grain is recommended for form-grinding.

11. Always keep the face of the wheel true by frequent use of a diamond.

12. When surface grinding dry, do not let the wheel glaze. As soon as it shows a black spot indicating glazing, use a carborundum or aloxite block, depending on the abrasive used in the wheel.

13. Do not take heavy cuts with ring, cylinder or cup-wheels which grind on the edge, and use comparatively high work speeds.

* * *

AVOID UNNECESSARY PURCHASES

It hardly seems necessary to say that it is poor business management to purchase unnecessary equipment, whether it be intended for the home, the office or the factory. But many concerns are burdened by expenditures for equipment not needed, and which can never be made profitable. It is a case oftentimes of not knowing what is already available or what with slight changes could be made so. Take the case, for example, of shop trucks. They are constantly in demand throughout the plant, and if not promptly returned to some central spot much time is lost by the men in looking for them. The conclusion may be jumped at that more trucks are needed, when as a matter of fact there are plenty but no system is applied to effect their return when the workmen have used them. A rearrangement of machinery groups or a more systematic handling of materials that makes machines more effective may eliminate the necessity of purchasing more machines. To make equipment more efficient by re-arranging and facilitating movement of the work to and from the machines is obviously better management than building additions and installing more machinery.

* * *

In the exhibit of the United States Steel Corporation at the Panama-Pacific Exposition in San Francisco, more than six miles of motion picture films are shown to give visitors an idea of the operations required to convert iron ore into finished products. Those familiar with motion picture films know that each foot contains sixteen small pictures, ¾ by 1 inch. In six miles of films, therefore, there are somewhat more than 500,000 individual pictures, each slightly different from the one immediately preceding. In these 500,000 pictures is shown the entire "story of steel."

CHARTS FOR DETERMINING SIZES OF TRANSMISSION SHAFTS*

BY JOSEF Y. DAHLSTRAND†

The relation existing between the power transmitted by a shaft and the diameter of the shaft and its torsional stress, when the shaft is subjected only to a torsional stress and is running at a certain number of revolutions per minute, can be expressed by the following equation:

$$\frac{12 \times 33{,}000 \text{ H.P.}}{2\pi \text{ R.P.M.}} = \frac{S_t \pi D^3}{16} \qquad (1)$$

where H.P. = horsepower transmitted by shaft;
R.P.M. = number of revolutions per minute made by shaft;
S_t = torsional stress in shaft in pounds per square inch;
D = diameter of shaft in inches.

The preceding equation is one which the engineering department of almost every manufacturing plant has occasion to use. This is especially the case in factories engaged in the manufacture of turbines or motors, which are direct connected to fans, pumps, generators, and similar units where couplings are required between the driving and the driven members. The speed and power is varied to suit different conditions, and the shaft ends to which the coupling is connected have to be proportioned accordingly. If a number of couplings have been adopted as standards, with their respective bores of the proper sizes to receive different standard shaft ends, it is necessary to check up these dimensions against the power and speed conditions for each case in order that the most suitable size of coupling may be selected. It often happens that one manufacturer furnishes the turbine, motor or other driving member, while another manufacturer furnishes the fan, pump, generator, or other driven member; and in such cases the shaft end of either the driving or driven member frequently has to be made special to suit the coupling. This makes it necessary to check up the torsional stresses to be sure that they do not exceed the highest value that is suitable for the material from which the shaft is made.

The chart shown in Fig. 1 has been found extremely useful for determining the relation between the diameter of the shaft and the amount of power it is capable of transmitting, the chart being used both for determining the required shaft diameter to transmit a given amount of power and for checking up the capacities of existing transmission systems. Aside from the amount of time which is saved through the use of this chart, it has been found of value in eliminating errors which sometimes find their way into results obtained by calculation. The well-known fact that the amount of power transmitted by a shaft of given diameter, which is subjected to a certain torsional stress, is directly proportional to the speed at which the shaft is running can be readily seen from Formula (1). Sometimes it is found convenient to use the number of horsepower transmitted per hundred revolutions per minute as the unit of power transmitted by a given shaft at different speeds; and the curves shown in Fig. 1 (the curves on the right-hand side are a continuation of those on the left) represent the values of this unit for different sizes of shafts subjected to torsional stresses of 3000, 5000, and 7000 pounds per square inch, respectively.

As an example of the uses of this chart, consider a case in which it is assumed that a steam turbine developing 900 horsepower and running at a speed of 2000 revolutions per minute is to be coupled to a generator. It is desired to find the proper diameter of the shaft at the coupling, that will safely transmit the power from the turbine to the generator, it being assumed that it is the practice of the manufacturer to allow a maximum torsional stress of 5000 pounds per square inch for the shaft. Dividing 900 by 20, it is found that (so

* For other articles on determining the diameter of shafting and allied subjects, published in MACHINERY, see also: "The Angle of Torsion," by B. D. Pinkney, November, 1914; "Heavy-duty Shafts with Two and Three Bearings," by W. G. Dunkley, April, 1914; "On Determining Shaft Diameters," by W. G. Dunkley, August, 1913; "Intermediate Supports for Long Shafts," by W. G. Dunkley, January, 1913; "Calculation of Bending and Turning Moments for Round Shafts," July, 1911; "Hollow Shafts," by E. Hammarstrom, April, 1911; "The Effect of Keyways on the Strength of Shafts," January, 1911; and "Table for Computing Hollow and Solid Shafting," September, 1905.

† Address: Care of Kerr Turbine Co., Wellsville, N. Y.

far as the torsional stresses are concerned) 45 horsepower per hundred revolutions per minute is equivalent to 900 horsepower at a shaft speed of 2000 revolutions per minute. From the 5000-pound curve in Fig. 1, the minimum shaft size is found to be 3.08 inches in diameter. The chart is used not only for determining the sizes of shaft ends to fit into a coupling; it can also be employed for determining the diameter of any shaft which is subjected only to torsional stresses. In cases where the bearing supports are close together, so that the stresses due to bending are small as compared with the torsional stresses, the curves can be used for finding the shaft size after all other considerations such as deflection and rigidity have been properly looked after.

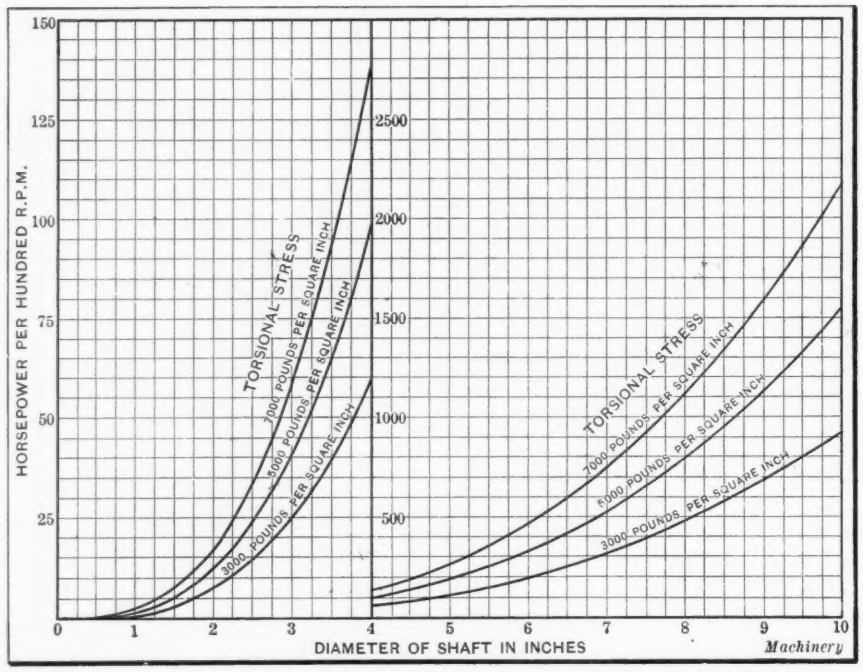


Fig. 1. Chart for determining Required Diameter of Shaft to transmit Various Numbers of Horsepower per Hundred R. P. M. for Torsional Stresses of 3000, 5000, and 7000 Pounds per Square Inch in Shaft

The three curves shown at the left-hand side of Fig. 2 are used for determining the required size of keys to use in a shaft, coupling, pulley, gear, or similar member which has to transmit a specified amount of power at a certain number of revolutions per minute, and with a fixed shearing stress per square inch in the key. The following formula shows the conditions which fix the value of the shearing stress S_s.

$$\frac{12 \times 33{,}000 \text{ H.P.}}{2\pi \text{ R.P.M.}} = \frac{S_s A D}{2} \qquad (2)$$

where H.P., R.P.M. and D have the values already given;

A = total shear area of key in square inches;

S_s = shearing stress in key in pounds per square inch.

These three curves at the left-hand side of Fig. 2 are plotted on the basis of horsepower transmitted per hundred revolutions per minute by one square inch shear area, with 2500, 4000, and 5500 pounds per square inch shearing stress in the key, respectively. On the right-hand side in Fig. 2 curves are drawn for the sake of convenience. which give the total shear area for different total lengths of keys, ranging in width from ¼ to 2 inches.

As an illustration of the use of this chart, suppose it is necessary to determine the size of keys that must be used in the coupling for connecting the turbine and generator of the unit referred to in the preceding problem, assuming that the manufacturer allows a maximum shearing stress of 4000 pounds per square inch in the key. It is also assumed that 3.125 inches was settled upon as the proper diameter of the shaft end instead of the value 3.08 inches which was determined in the preceding problem. On the 4000-pound stress-curve in Fig. 2, it is found that 1 square inch of key-area is capable of transmitting 10 horsepower per hundred revolutions per minute, with this shaft diameter. Thus the transmission must have 4.5 square inches of key-area in order to transmit 45 horsepower at 100 R. P. M. or, what amounts to the same thing (so far as the shearing stresses in the keys are concerned) to transmit 900 horsepower at 2000 revolutions per minute. From the curves on the right-hand side in Fig. 2, it is seen that if two keys are to be used and the coupling fit made 5 inches long, giving a total key length of 10 inches, the keys would have to be made about 7/16 inch wide, or ⅞ inch in width if only one key were used.

The stresses allowed in each separate case are naturally dependent on the material and the uniformity with which the power is transmitted. For the best grades of steel and for a uniform load, a torsional stress of 7000 pounds per square inch in the shaft, and a shearing stress of 5500 pounds per square inch in the keys, gives a satisfactory factor of safety. For cases where the load is not uniform, lower stresses should be used, an allowance of 5000 pounds torsional stress and 4000 pounds shearing stress being representative of ordinary practice in designing the shaft ends of small steam turbines. In proportioning keys, it is common practice to make the height of the key equal to the width, so that the total crushing area is made half of the total shear area, on the assumption that the keys enter the shaft to the same depth as they enter the coupling or pulley. This is satisfactory so far as the keys and the shaft are concerned, but it may result in allowing too high values of the crushing stress for the material of the bored member, especially if the material is cast iron. In such cases, the curves in Fig. 2 may be used for determining the proper crushing area for a certain allowable crushing stress, in a similar manner to that employed when finding the shear area, and the keys are then proportioned accordingly.

These charts have been found useful by the writer in designing turbine shafts.

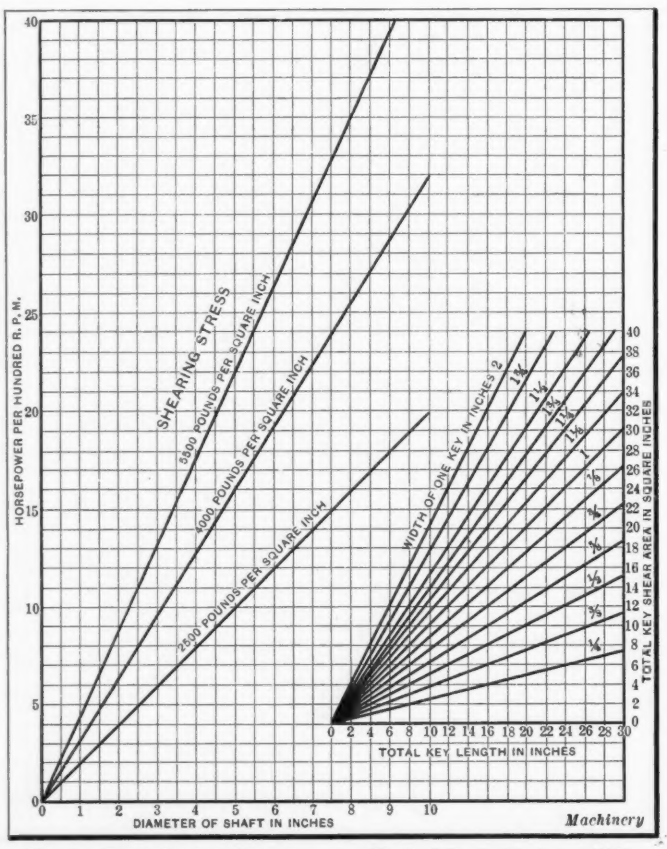

HORSEPOWER PER HUNDRED R. P. M.
DIAMETER OF SHAFT IN INCHES
SHEARING STRESS
5500 POUNDS PER SQUARE INCH
4000 POUNDS PER SQUARE INCH
2500 POUNDS PER SQUARE INCH
WIDTH OF ONE KEY IN INCHES
TOTAL KEY LENGTH IN INCHES
TOTAL KEY SHEAR AREA IN SQUARE INCHES
Machinery

Fig. 2. Chart showing Horsepower per Hundred R. P. M. transmitted by One Square Inch of Key Area for Shafts of Various Diameters; Also Total Key Area for Keys of Various Widths and Lengths

GEAR DIAGRAMS*

METHODS FOR THE RAPID SOLUTION OF PROBLEMS IN GEAR DESIGN

BY H. D. HESS†

THE designing of gears by the usual method of trial is a tedious if not a difficult problem for the draftsman who has not had considerable experience with work of this nature; and even the experienced designer frequently spends a lot of time before he obtains a satisfactory solution. For the purpose of affording a rapid method of handling problems in gear design, the writer developed a set of gear diagrams based on the Lewis formula, which forms the subject of this article. He has found them to be of considerable value in his own work, and they are presented with the hope that they may prove of equal value to other readers of MACHINERY. The significance of the symbols which are used in the text is as follows:

M = twisting moment, in inch-pounds;
H. P. = horsepower;
N = revolutions per minute;

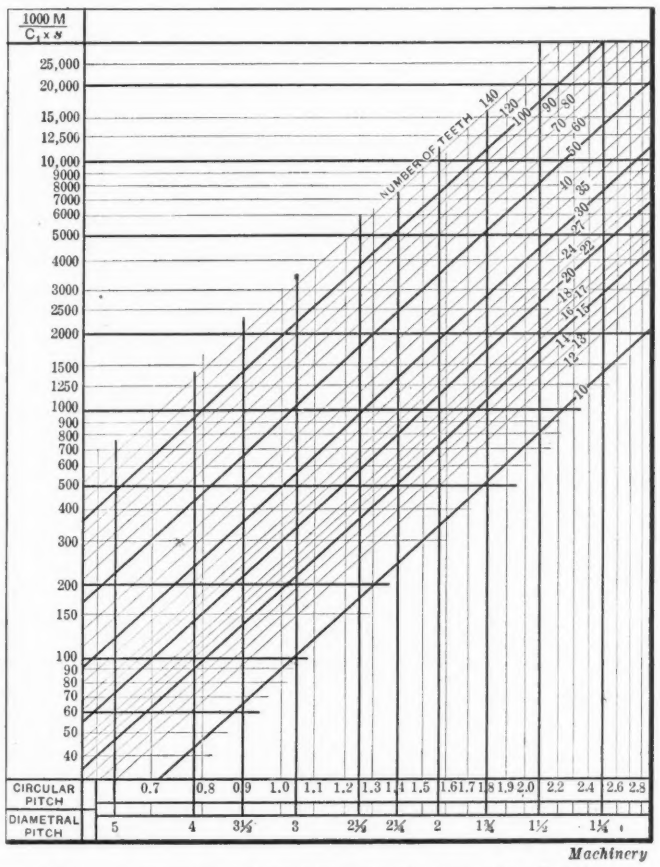


Fig. 1. Diagram for determining Required Pitch when Twisting Moment, Permissible Fiber Stress, and Ratio of Face Width to Circular Pitch are known

W = force acting on the face of a tooth, in pounds;
s = allowable working fiber-stress on the tooth at the velocity v, in pounds per square inch;
f = width of the tooth face, in inches;
n = number of teeth in the pinion or gear, depending upon which is being considered at the time;
r = radius of the gear or pinion, in inches;
p_c = circular pitch, in inches;
p_d = diametral pitch;
A and B = ordinates in the diagram;
v = velocity in feet per minute at the pitch circle;
C_1 = constant depending on the ratio of face width to the circular pitch;
C_2 = constant depending on the material and the desired working fiber-stresses.

* For additional information on the strength of gear teeth see also "Convenient Form of Lewis Formula for Strength of Gear Teeth," by J. H. Carver, published in MACHINERY for October, 1914, and other articles there referred to.

† Address: Sibley College of Mechanical Engineering, Cornell University, Ithaca, N. Y.

The basis of the diagrams is the Lewis formula:

$$W = sp_c f\left(0.124 - \frac{0.684}{n}\right).$$

The diagram shown in Fig. 1 is intended to give the pitch when the twisting moment transmitted by the pinion or gear, the desired working fiber-stress and the ratio of face width to circular pitch are known. The diagram shown in Fig. 2 is quite similar, excepting that in this case the face width in inches is assumed. The algebraic calculations are as follows for 14½-degree involute teeth of standard height:

$$W = sp_c f\left(0.124 - \frac{0.684}{n}\right) \qquad (1)$$

$$M = Wr = sfnp_c^2\left(0.124 - \frac{0.684}{n}\right) \qquad (2)$$

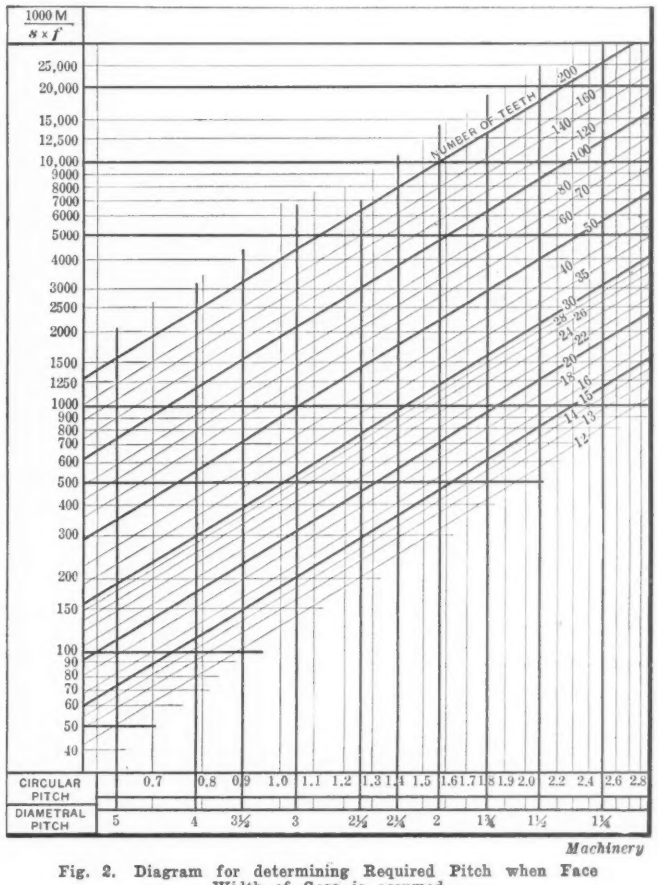


Fig. 2. Diagram for determining Required Pitch when Face Width of Gear is assumed

Substituting for r its value $\frac{np_c}{2\pi}$ we have:

$$M = \frac{sf\,np_c^2}{6.28}\left(0.124 - \frac{0.684}{n}\right) \qquad (3)$$

$$\frac{1000\,M}{sf} = \frac{1000\,np_c^2}{6.28}\left(0.124 - \frac{0.684}{n}\right) \qquad (4)$$

The quantity 1000 has simply been inserted on both sides of the equation to eliminate decimals. Equation (4) has been used to plot the diagram shown in Fig. 2.

If $f = C_1 p_c$ we have:

$$\frac{1000\,M}{sC_1} = \frac{1000\,np_c^3}{6.28}\left(0.124 - \frac{0.684}{n}\right) \qquad (5)$$

Equation (5) has been used to plot the diagram Fig. 1.

The solution of the following problems will serve to illustrate the use of the diagrams shown in Figs. 1 and 2.

Problem 1.—Considering the strength only, what pitch will be required for a 15-tooth, cast-iron pinion, to transmit 20

horsepower when making 225 revolutions per minute? The fiber-stress is not to exceed 6000 pounds per square inch, and the face width is 3.25 inches.

The twisting moment on the pinion shaft is:

$$M = \frac{63{,}025 \text{ H. P.}}{N} = \frac{63{,}025 \times 20}{225} = 5600 \text{ inch-pounds.}$$

Consulting the diagram Fig. 2 for $\frac{1000\,M}{6000 \times 3.25} = \frac{1000 \times 5600}{6000 \times 3.25} = 287$, we find that the required circular pitch, for $n = 15$, is 1.24 inch, which corresponds to a diametral pitch of 2.5.

Problem 2.—In Problem 1, if the ratio of face width to the circular pitch had been given, the diagram in Fig. 1 would have been used. Taking the same problem and assuming $f \div p_c = C_1 = 2$, the solution would be as follows:

$$\frac{1000\,M}{sC_1} = \frac{1000 \times 5600}{6000 \times 2} = 467.$$

The circular pitch given by the diagram Fig. 1, corresponding to the ordinate 467 and 15 teeth, is $p_c = 1.36$ inch; and the required face width would be $1.36 \times 2 = 2.72$ inches.

The diagrams shown in Figs. 3 and 4 are intended to permit of the selection of the proper pitch when the horsepower which is being transmitted or the twisting moment is known, together with the materials of which the gears are made, the number of revolutions per minute, and the law of reduction of the working fiber-stress with the increase of velocity. This law has been assumed as given by the heavy curves in the diagram presented in Fig. 5. The assumption for cast iron is that for velocities of the teeth at the pitch circle exceeding 100 feet per minute, the fiber-stress for cast iron may vary as $\frac{88{,}000}{\sqrt{v}}$. If the material is steel the fiber-stress may be taken as $\frac{220{,}000}{\sqrt{v}}$. These stresses were suggested by C. R. Whittier in MACHINERY for August, 1909, and agree very closely with those suggested by Wilfred Lewis for use with his formula. The purpose of the diagrams in Figs. 3 and 4 has been to provide charts that would avoid the necessity of making an initial guess as to the gear proportions in order to find the force W acting on the teeth and the allowable fiber-stress. In designing gears, either the horsepower they are to transmit and the number of revolutions per minute, or the twisting moment and the number of revolutions per minute will be given. When the horsepower and the number of revolutions per minute are given, the twisting moment is readily found from the relation:

$$M = \frac{63{,}025 \text{ H. P.}}{N}.$$

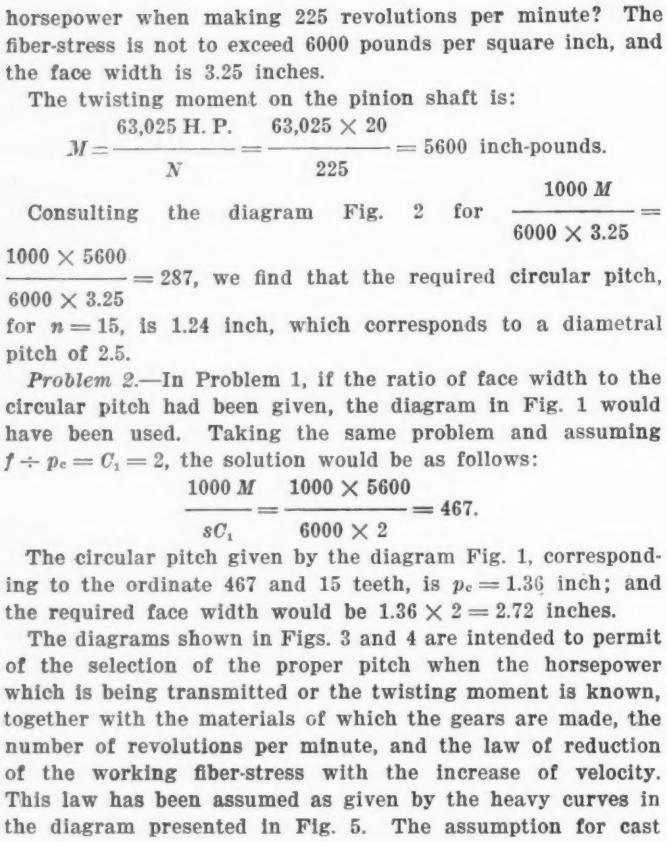


Fig. 3. Diagram for determining Required Pitch when Horsepower or Torque, R. P. M., Material and Ratio of Face Width to Circular Pitch are known

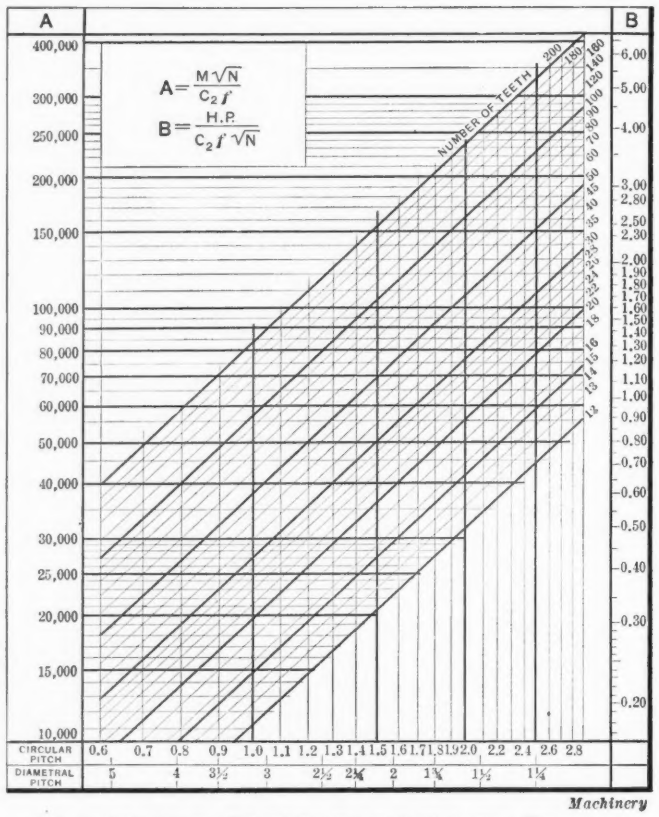


Fig. 4. Diagram for determining Required Pitch when Horsepower or Torque, R. P. M., and Material are known and Face Width of Gears is assumed

Formula (1) is now transformed by substituting the following values:

$$W = sp_c f \left(0.124 - \frac{0.684}{n}\right) \qquad (1)$$

$$s = \frac{88{,}000}{\sqrt{v}} \text{ (for cast iron)}$$

$$r = \frac{np_c}{6.28}$$

$$v = \frac{np_cN}{12} = \frac{rN}{1.91} = \frac{nN}{3.82p_d}$$

Hence

$$M = Wr = \frac{88{,}000\sqrt{12}}{\sqrt{np_cN}} \times p_c \times f \times \frac{np_c}{6.28}\left(0.124 - \frac{0.684}{n}\right) \qquad (6)$$

$$MN^{\frac{1}{2}} = 48{,}540\, n^{\frac{1}{2}}\, p_c^{\frac{3}{2}}\, f \left(0.124 - \frac{0.684}{n}\right) \qquad (7)$$

The diagram shown in Fig. 4 has been drawn for a face width of f inches so that:

$$\frac{MN^{\frac{1}{2}}}{f} = 48{,}540\, n^{\frac{1}{2}}\, p_c^{\frac{3}{2}} \left(0.124 - \frac{0.684}{n}\right) \qquad (8)$$

In the diagram shown in Fig. 3, $f = C_1 p_c$ so that:

$$\frac{MN^{\frac{1}{2}}}{C_1} = 48{,}540\, n^{\frac{1}{2}}\, p_c^{\frac{2}{2}} \left(0.124 - \frac{0.684}{n}\right) \qquad (9)$$

The working fiber-stresses for cast iron and steel are given by the diagram Fig. 5, as recommended by Mr. Lewis, and as

suggested by Carl Barth and used with his slide-rule; and they are also given as conforming to the quantities $\frac{88,000}{\sqrt{v}}$ and $\frac{220,000}{\sqrt{v}}$, respectively. This leads to the introduction of a factor C_2 in the diagrams, Figs. 3 and 4. The value of C_2 for cast iron is 1; and this basis of the stress in cast iron corresponds to Lewis' value of a maximum of 8000 pounds per square inch at a velocity of 100 feet per minute. To plot the assumed curve for any other material or fiber-stress, multiply the quantity $\frac{88,000}{\sqrt{v}}$ by the ratio of the maximum desired fiber-stress to 8000; thus steel with an allowable fiber-stress of 20,000 pounds per square inch at a peripheral speed of 100 feet per minute, gives a ratio of $\frac{20,000}{8000} = 2.5$ and the quantity becomes $\frac{88,000 \times 2.5}{\sqrt{v}} = \frac{220,000}{\sqrt{v}}$. The curves thus constructed give values exceeding the maximum, for values of v below and approximating 100 feet per minute, so that the diagrams should be used with caution for these low values of v. On the diagram Fig. 5, the fiber-stresses have also been plotted for a maximum fiber-stress of 15,000 pounds per square inch at a speed of 100 feet per minute. This may be used for steel castings although some designers use 20,000 pounds per square inch on both rolled steel and steel castings.

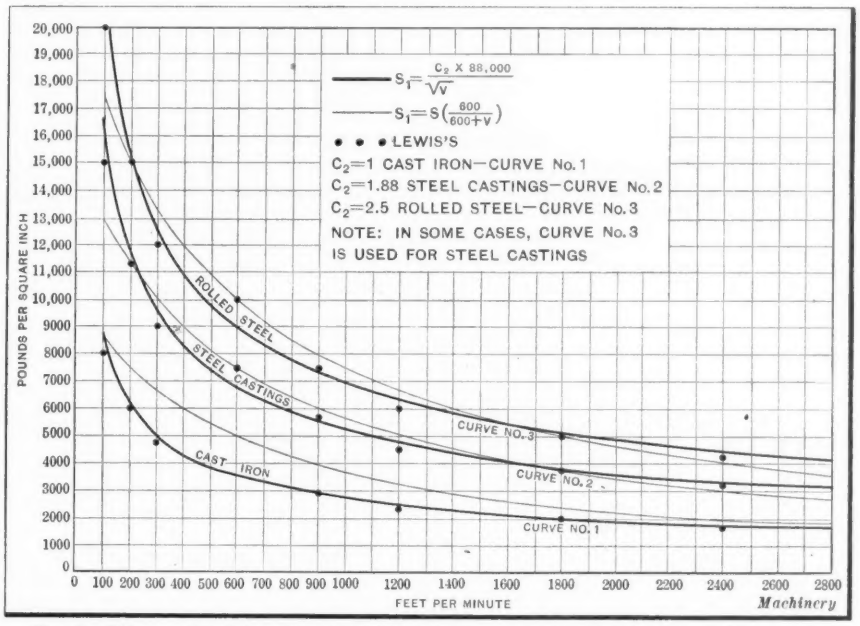


Fig. 5. Diagram for determining Safe Fiber-stress for Various Speeds met with in Practice

The ordinates for the diagram shown in Fig. 3 are:

$$A = \frac{M\sqrt{N}}{C_1 C_2} \text{ and } B = \frac{\text{H.P.}}{C_1 C_2 \sqrt{N}}.$$

The ordinates for the diagram shown in Fig. 4 are:

$$A = \frac{M\sqrt{N}}{C_2 f} \text{ and } B = \frac{\text{H.P.}}{C_2 f \sqrt{N}}.$$

The solution of the following problems will serve the purpose of illustrating the method of using these diagrams.

Problem 3.—Design a pair of gears to transmit 25 H. P. at 150 revolutions per minute of the pinion, with a reduction of 5 to 1 to the gear. Assume both the gear and pinion to be made of cast iron, and that the desired fiber-stress will vary as given in the diagram Fig. 5 inversely with the square-root of the velocity at the pitch circle. Take the face as 3 times the circular pitch, and assume the pinion has 15 teeth.

As the gear and pinion are of the same material, the pinion teeth will be the weaker and we need only design for it. To use the diagram Fig. 3, we find:

$$B = \frac{\text{H. P.}}{C_1 C_2 \sqrt{N}} = \frac{25}{3 \times 1 \times \sqrt{150}} = 0.68.$$

In this diagram, for $B = 0.68$ and $n = 15$, we find $p_c = 1.52$ inch. This would make the face width $1.52 \times 3 = 4.56$ inches. Using the nearest stronger diametral pitch would require 2 diametral pitch, and the face could be made 4.5 inches. The pitch diameter of the pinion is $\frac{\text{number of teeth}}{\text{diametral pitch}} = \frac{15}{2} =$ 7.5 inches. The gear diameter is $7.5 \times 5 = 37.5$ inches. If desired, the velocity at the pitch line and the working fiber-stress may be found. The velocity is $v = \frac{nN}{3.83\, p_d} = \frac{15 \times 150}{3.83 \times 2}$ = 295 feet per minute. The diagram Fig. 5 gives the fiber stress corresponding to this velocity as 5000 pounds per square inch.

Problem 4.—The conditions of this problem will be the same as in Problem 3, excepting that the face width will be assumed as 3.75 inches. The solution requires the use of the diagram shown in Fig. 4.

$$B = \frac{\text{H. P.}}{C_2 f \sqrt{N}} = \frac{25}{1 \times 3.75 \sqrt{150}} = 0.545.$$

From Fig. 4 the circular pitch corresponding to $B = 0.545$ and $n = 15$ is $p_c = 1.74$ inch; and this is approximately equal to a diametral pitch of 1.75. The pitch diameter of the pinion then is $\frac{n}{p_d} = \frac{15}{1.75} = 8.57$ inches, while the pitch diameter of the gear is $\frac{75}{1.75} = 42.86$ inches. The face width, as assumed, is 3.75 inches.

Problem 5.—The conditions of this problem are also like those of Problem 3. The twisting moment on the pinion shaft is 10,500 inch-pounds, but the pinion and gear are made of different materials. Assume the pinion to be made of forged or rolled steel and the gear of cast iron. The fiber-stresses will be those given by the diagram Fig. 5, for the upper and lower curves. Considering first the pinion, the twisting moment M on the pinion shaft is 10,500 inch-pounds and the face width will be taken as three times the circular pitch. In the diagram Fig. 3, we have:

$$A = \frac{M\sqrt{N}}{C_1 C_2}.$$

For rolled steel $C_2 = 2.5$ and in this problem $C_1 = 3$.

$$A = \frac{10,500\sqrt{150}}{3 \times 2.5} = 17,150.$$

For $A = 17,150$ and $n = 15$ the diagram gives $p_c = 1.06$ inch. Now for the gear, the twisting moment M will be 10,500 $\times 5 = 52,500$ inch-pounds and $N = \frac{150}{5} = 30$. For cast iron $C_1 = 1$.

$$A = \frac{M\sqrt{N}}{C_1 C_2} = \frac{52,500 \times \sqrt{30}}{1 \times 3} = 96,000.$$

In the diagram Fig. 3, $p_c = 1.32$ inch, for $A = 96,000$ and $n = 75$. Comparing the pitches found for the gear and the pinion, it is seen that the gear requires the greater pitch and since they must be alike the 1.32-inch circular pitch must be used. The face width will be $1.32 \times 3 = 3.96$ inches or approximately 4 inches. The nearest stronger diametral pitch is 2.25. On the basis of diametral pitch, the pitch diameter of the pinion will be $\frac{15}{2.25} = 6.67$ inches. The pitch diameter of the gear is $\frac{75}{2.25} = 33.33$ inches. The face width is 4 inches, as previously stated.

When the desired fiber-stress does not follow the curves assumed, the pitch is not quite so readily obtained from the diagrams but may be determined as follows:

Problem 6.—In Problem 1, instead of giving the fiber-stress we will assume that it is required to follow the curve representing Mr. Barth's equation, shown in the diagram Fig. 5, for cast iron. Assuming that one has no idea what the pinion diameter will be, it is better to first find the pitch required as if the allowable fiber-stress varies as $\frac{88{,}000}{\sqrt{v}}$.

$$A = \frac{M\sqrt{N}}{C_2 f} = \frac{5600\sqrt{225}}{C_2 \times 3.25} = 25{,}800.$$

From the diagram Fig. 4, $p_c = 1.45$ inch; and the value of v corresponding to this pitch is:

$$v = \frac{np_cN}{12} = \frac{15 \times 1.45 \times 225}{12} = 408$$ or approximately 400 feet per minute.

It will be sufficiently close to assume that the relation between the working fiber-stresses at the actual velocities will approximate that for 400 feet per minute. From the diagram Fig. 5, the fiber-stresses at 400 feet per minute, according to Barth's (light line) and the heavy line curve, are 6000 and 4400 pounds per square inch, respectively. The ratio of these stresses is $\frac{6000}{4400} = 1.36$. In Formula (6) from the diagram Fig. 4, for cast iron:

$$M = Wr = \frac{88{,}000\sqrt{12}}{\sqrt{np_cN}} \times p_c f \times \frac{np_c}{6.28}\left(0.124 - \frac{0.684}{n}\right).$$

If the twisting moment or the horsepower is to remain constant while the fiber-stress, stated in the portion $\frac{88{,}000\sqrt{12}}{\sqrt{np_cN}}$ varies, then p_c must change to preserve the equality. If the ratio of the two fiber-stresses is a, then p_c must vary inversely with the factor $\rho = a^{\frac{3}{2}}$, *i.e.*, the cube-root of its square. To use the diagram, $a^{\frac{3}{2}} = 1.36^{\frac{3}{2}} = 1.23$. The corrected pitch then is $\frac{p_c}{\rho} = \frac{1.45}{1.23} = 1.18$ inch. Had the ratio of the face width to the circular pitch been given, instead of the width of the tooth face in inches, then the factor would have been $\rho = a^{\frac{2}{5}}$, and the diagram Fig. 3 would have been used. Another problem will illustrate the last suggestion.

Problem 7.—Design a pair of gears to transmit 80 horsepower, the pinion to be steel with 18 teeth while the gear will be cast iron with 90 teeth. The ratio of the face width to the circular pitch will be 4 to 1; and the allowable fiber-stress on the pinion shall be that given in the diagram Fig. 5 for steel. For cast iron, Barth's curve shall be used. The pinion runs at 400 revolutions per minute.

For the pinion, $C_1 = 4$ and $C_2 = 2.5$.

$$B = \frac{\text{H. P.}}{C_1 C_2 \sqrt{N}} = \frac{80}{4 \times 2.5\sqrt{400}} = 0.40.$$

Then from the diagram Fig. 3, $p_c = 1.15$ inch. For the gear, $C_1 = 4$ and $C_2 = 1$.

$$B = \frac{\text{H. P.}}{C_1 C_2 \sqrt{N}} = \frac{80}{4 \times 1\sqrt{80}} = 2.23.$$

Then from the diagram Fig. 3 p_c corresponding to $B = 2.23$ for 90 teeth is 1.46 inch. This is the value which must be used, as it is the greater of the two pitches. The velocity at the pitch line of the gear is $\frac{1.46 \times 90 \times 80}{12} = 876$ feet per minute. From the diagram Fig. 5, the allowable fiber-stress given by the two curves is 4000 and 3000 pounds per square inch, respectively. From these values:

$$a = \frac{4000}{3000} = 1.33.$$

$$\rho = a^{\frac{3}{2}} = 1.33^{\frac{3}{2}} = 1.12.$$

Hence the revised circular pitch is $\frac{p_c}{1.12} = \frac{1.46}{1.12} = 1.30$ inch.

The diameter of the pinion is $\frac{1.30 \times 18}{3.14} = 7.45$ inches.

The diameter of the gear is $\frac{1.30 \times 90}{3.14} = 37.24$ inches.

Instead of changing the circular pitch, the working-stress in the teeth might have been increased by reducing the width of the face, as the fiber-stress and the width of the face vary inversely with each other. The gear with 3000 pounds per square inch fiber-stress had $p_c = 1.46$ inch, so that the gear diameter is $\frac{1.46 \times 90}{3.14} = 41.82$ inches, while the pinion diameter is $\frac{1.46 \times 18}{3.14} = 8.37$ inches. The face width is $1.46 \times 4 = 5.84$ inches. Had it been deemed desirable to use a narrower face width, the face could have been made $\frac{3}{4} \times 5.84 = 4.38$ inches; and this would have increased the fiber-stress from 3000 to 4000 pounds per square inch, which is the desired limiting fiber-stress.

Similar diagrams may be used for the design of gears with stub teeth or for other ranges of pitches. The diagrams give the minimum pitches and consequently the smallest diameters for the given conditions. Where the frame conditions require larger gears, owing to the desired distance between the gear centers, the pitch found in the diagrams still gives a good suggestion as to the probable dimensions.

* * *

SCARCITY OF COPPER ALLOYS IN GERMANY

In the issue of July 30, of *Die Werkzeugmaschine*, a letter from the German war department to the Society of German Machine Tool Builders is published. This refers to a request made by the machine tool builders for brass and phosphor-bronze, which metals apparently have been entirely appropriated by the government. The letter states that the release of such quantities of brass and phosphor-bronze as had been requested would be impossible on account of the necessity for safeguarding the supplies necessary for the army for a long time to come. It is stated that while, without question, the elimination of copper alloys in the construction of machine tools would mean greater wear and heavier stresses in many machine details, these evils must be taken into consideration and accepted by the buyer during the war. According to the opinions of experts, however, cast iron can be used, says the war department, for all journal bushings where the revolutions per minute do not exceed 300 to 400. Cast iron, as well as hardened steel, can safely be run in cast-iron bearings. When machine steel is used in cast-iron bearings, the machine steel journal should be casehardened. White metal bearings are also, at the present time, recommended in place of brass and bronze bushings. The lubrication should be suited to the metals used in bearings, ring oiling, forced lubrication, etc., being preferable. Graphite should be used when running-in journals to produce a smooth surface. The letter ends with a further request to the machine tool builders to regard these points in machine tool construction, and to consider it a duty to use the greatest economy in the employment of metals which the government considers it necessary to save.

* * *

The United States government has installed an eight-effect distilling plant for supplying water to a fortification where fresh water is not available. The apparatus, of the Lillie design, is of the reversible type. The hot effects can be made the cool effects, and *vice versa;* the object of reversibility is to reduce the scaling to a minimum. The efficiency obtained is six pounds of distilled water per pound of steam at forty-five pounds gage pressure. The apparatus cost about $16,500 complete with boilers and auxiliaries and has a capacity of 7000 gallons per day of twenty-four hours. The cost per gallon of distilled water when the plant is run twenty-four hours a day, 300 days to the year, is one-quarter cent, coal being charged at $3.50 per ton. This charge includes a depreciation charge of 12 per cent on the investment.

A PROBLEM IN SLOTTING AND INDEXING

BY DONALD A. HAMPSON*

Several interesting points were presented by a certain contract job that was recently handled in our shop, and I have prepared the following description of our method of doing the work with the hope that it may prove of interest to some of MACHINERY'S readers. The part with which this article concerns itself consisted of machining three cast-iron rings, which were 34 inches outside diameter, 23 inches inside diameter and 1 inch in thickness. After machining these castings, it was necessary to cut radial T-slots across their faces. There were twenty slots cut in the first ring, forty in the second and sixty in the third. These slots were ½ inch wide with a total depth of 9/16 inch, and were under-cut

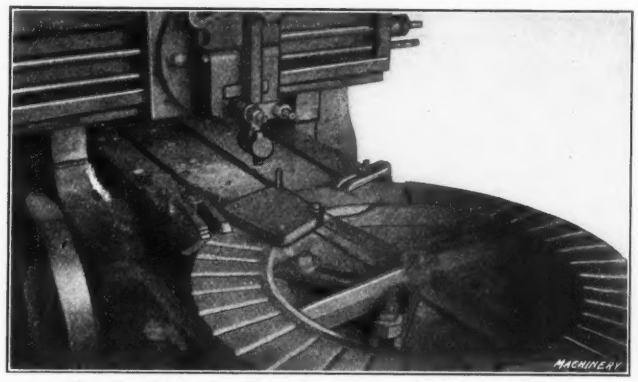


Fig. 1. Set-up for First Operation performed on Planer

for bolt heads ¼ by 1 inch in size. As shown in the accompanying illustrations, some of the slots were widened out at the ends, but this has no particular connection with the way in which the work was handled.

Just how to index these slots correctly and still handle the work economically caused considerable speculation, and required some of us to give the problem a good deal of thought. Safety in handling was of primary importance because breaking a ring of these dimensions was an ever-present possibility, and would have involved a serious delay and loss in labor charges. Index centers of the ordinary type could not be employed in this case, and laying out the work would not give the required degree of accuracy. The fixtures that were finally made for handling this job are shown in Figs. 1 and 2, which also show the work in two different stages. The method of procedure consisted in taking stocking cuts of the full ½ inch in width and of nearly the full depth on the planer, then doing the T-slotting with a standard T-slot cutter used in the milling machine. The greatest permissible variation in the spacing was 0.005 inch at the outside of the rings.

The indexing fixtures used on the planer are shown in Fig. 1. They consist of a cast-iron spider 23 inches in diameter, that had a hole bored in the center, and was turned on the outside to the required size; a plug to go in the central hole of the spider; an index plate having holes for twenty, forty and sixty divisions; and an index pin. The center plug was tapped at its lower end and screwed down tightly against the planer table over a bolt placed in the middle T-slot. This plug was reduced to a diameter of ½ inch at its upper end, which was the same as the width of the slots to be cut, and by setting the slotting tools to this plug, the slots were cut exactly on the diameter. The spider was slipped over the plug and clamped securely in place. In making the index plate great care had to be exercised to insure having it of the required accuracy. The position of the plate on the spider was such that the work could be revolved below it; but this arrangement made it necessary for the index plate to be removed every time a fresh ring was put on the spider, and on this account substantial dowel-pins were provided in addition to two ½-inch cap-screws. There were four holes for the index pin, there being one zero hole and one hole for twenty, forty and sixty divisions, respectively, all of the holes being located on a circle 33 inches in diameter. These holes were located by the button method, and bored a close fit for an index pin ⅝ inch in diameter, so that the pin could be flattened on two sides to present a broader and larger wearing surface to the slots in the work. As the flattened sides were slightly tapered, they took care of variations in the width of the slots which might result from wearing of the tool.

Considerable care had to be exercised in setting the spider and index plate, for it will be evident that any error introduced at the start would be cumulative, *i. e.*, while all of the slots indexed would be equally spaced only thirty-nine indexings are required for a forty-slot ring, so that the last space would receive the entire error introduced at the start of the machining operation. This was the chief objection to the method of indexing that was employed, but by taking great care at the two "danger points"—spacing of the plate and setting the work for milling the first slot in the ring—the difficulty was overcome. In handling the work, the ring to be slotted was clamped in place and the first slot cut, the tool having been set central by means of the plug at the middle of the spider. The spider was next unclamped and swung around until the zero hole, which is on the right-hand side, was over the cut slot with the index pin firmly in place. After clamping the spider, the ring was turned to the left until the slot was under the forty hole (assuming a forty-slot ring is being handled), after which the index pin was slipped into this slot. The ring was next clamped and the spider unclamped and revolved until the zero hole once more lined up with the slot, after which the index pin was inserted and the spider permanently fastened. This resulted in locating the zero hole on a diameter exactly 9 degrees from the diameter covered by the slotting tool.

Twenty-, forty- and sixty-hole rings were handled by means of corresponding holes in the index plate, these holes only being used for the first setting, after which only the zero hole was used for successive indexing operations without requiring the spider to be moved. With the zero hole properly placed, the operation resolved itself into one of plain indexing, and the work was done so carefully that the sixty-slot ring showed a total error of 0.004 inch, while the error in the forty- and twenty-slot rings was only 0.006 inch. These results showed the care which was exercised in setting up the work to overcome the weak features of this method of indexing. The tool used for slotting was an Armstrong special planer tool-holder carrying two high-speed steel bits, one of which took the roughing cut and the other the sizing cut. This is shown in detail in Fig. 3. As the slots were planed 0.010 inch less than the required depth, the broken surface which the tools left in the bottom of the slots made no difference. Originally it was intended to make a special

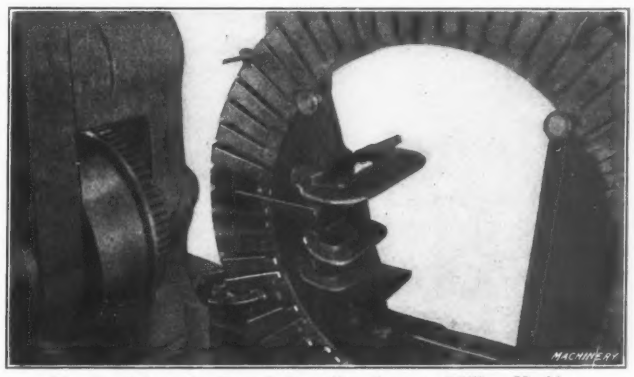


Fig. 2. Set-up for Second Operation done on Milling Machine

tool fixture, but by cutting the slot in the head bolt a little longer, the Armstrong holder answered the purpose required of it. Incidentally, this affords a good example of adapting a standard tool for a special job, as compared with the more expensive method of making up a special tool for the purpose.

After the slots were planed, it was necessary to under-cut them on a plain milling machine, no tools other than the shop's regular equipment being used for this purpose. Two or three points in connection with this part of the work are worthy of special mention. For holding the work, two 24-inch angle plates were bolted to the milling machine table with their surfaces slightly overhanging its edge. This method

* Address: 31 Hanford St., Middletown, N. Y.

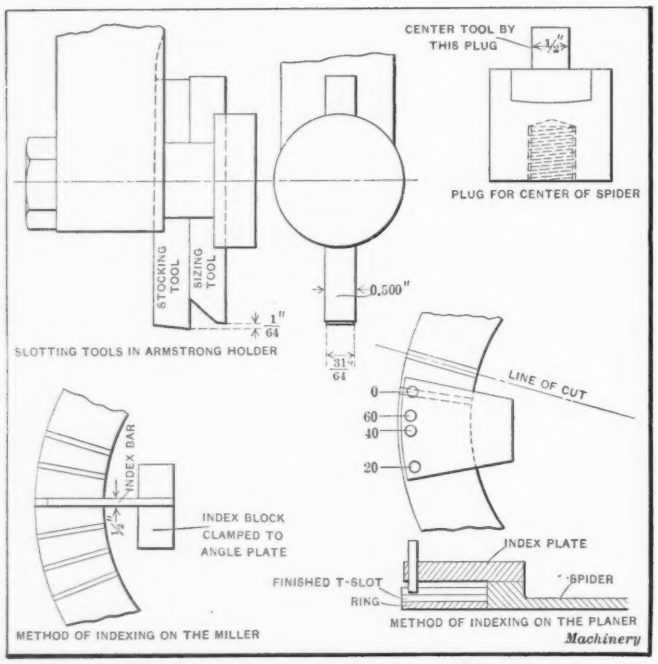


Fig. 3. Details of Tools used for Planing and Milling Operations

was resorted to because the capacity of the machine would not permit of the rings resting on top of the table, but with the angle plates they could be set up to extend about 6 inches below its working surface. As there was no center web to support the ring, the operation of shifting and re-aligning the work for each cut would have been a formidable one had it not been for the provision of two small rollers, which can be seen in Fig. 2 on the inside of the ring near the top. These rollers were mounted on shoulder bolts set in the angle plates, and served the triple purpose of centering the ring, forming anti-friction bearings on which to turn it, and by means of a flange on the inside of each roller, avoiding any chance of a ring slipping off and falling while the C-clamps were loosened for turning the work.

Ordinary T-slot cutters were used for the undercutting operation, and after the first slot was properly aligned and centered with the cutter, the work was located for subsequent operations by direct indexing. A piece of steel had a ½-inch slot cut in it and a second piece of steel ½ inch square was machined to fit snugly in the slot. The ½-inch bar was then laid in the aligned slot in the ring and in the piece of flat steel held against the angle plate. C-clamps fastened the bar in place, thus holding the work in the desired position. The work was then located for subsequent operations by loosening the clamps and turning the ring until the bar dropped into both the slot in the work and the index slot. That this method gave satisfactory results is evidenced by the fact that the entire milling operation was performed at an average rate of 8 minutes per slot, this time including everything except setting up the work ready for the first operation. The rollers on which the work was held on the angle plates made it possible for the milling machine operator to mill the rings without requiring any assistance.

* * *

DRILLING MOTORCYCLE HUBS

The drilling of the spoke holes in the hubs of "Indian" motorcycles at the factory of the Hendee Mfg. Co., Springfield, Mass., is a job worthy of mention. These hubs are made of low carbon steel and the end flanges through which the holes are drilled are one-eighth inch thick. Through each flange sixteen No. 25 holes are drilled at a slight angle so that the direction of the drilling is along the lines of a cone. The distance between the holes is about one-half inch.

The spindles of the multiple spindle drilling machine in which the work is done are guided in their inclination by a steel ring supported from the head of the machine. The jig is of the swiveling type, permitting the holes in one end of the hub to be drilled, after which the work-holding part of the jig is swiveled 180 degrees and the holes in the opposite end are drilled. The drilling is performed by running the head and drills down to the work, which on account of the inclination of the spindles is the only way possible.

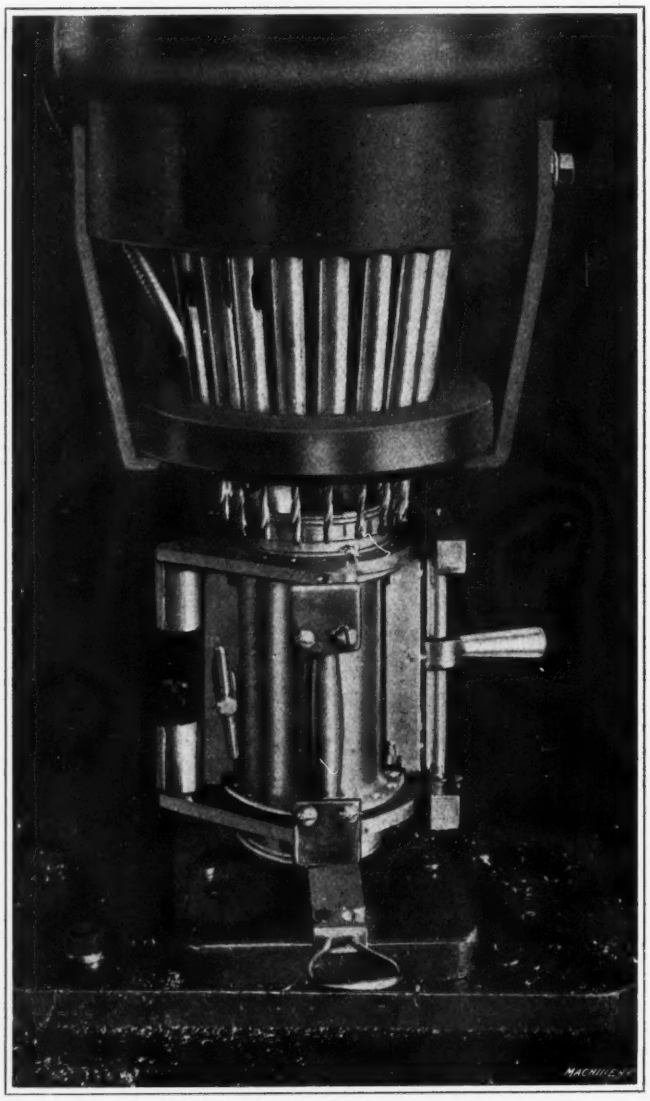
In order that the work may be quickly inserted and removed, the jig is made in halves. As the illustration shows, these halves are hinged at the left and held together for the drilling by a latch that appears at the right of the illustration. The drill bushings are located in the faces of the halves of the jig. After the holes in one flange of the hub have been drilled, the steel plate that takes the thrust is removed from beneath the work. Then by withdrawing the index pin at the left, the working part of the jig can be turned 180 degrees to present the other face of the hub to the drills. The heavy stud on which the jig swivels is directly behind the work and therefore not visible in the illustration. The index pin is inserted, the thrust plate is replaced and the drilling of the hub is completed. The hubs, each having thirty-two holes—sixteen to each end—are drilled at the rate of 300 per ten-hour day. C. L. L.

* * *

CONSUMPTION OF OIL FUEL FOR FORGE FIRES

In order that forge fires may be operated economically, there should not be an abundance of flame passing out of the door openings of the furnace. Greater heat and economy of fuel are secured by so regulating the burners that only a greenish haze about six inches long is visible passing out of the furnace doors when opened. With the correct number of burners properly adjusted for the capacity of the furnace, the average consumption of oil when heating for a 1000-pound steam hammer is 3½ to 4½ gallons per hour. It has been found in one of the foremost forge plants in this country that nineteen pounds of steel can be heated to each gallon of oil consumed. The steel used is chiefly vanadium alloy.

D. T. H.



Swiveling Drill Jig for Motorcycle Hubs

PUNCH AND DIE STANDARDS

APPLICATION OF MANUFACTURING METHODS IN TOOLMAKING OPERATIONS

BY EDWARD K. HAMMOND*

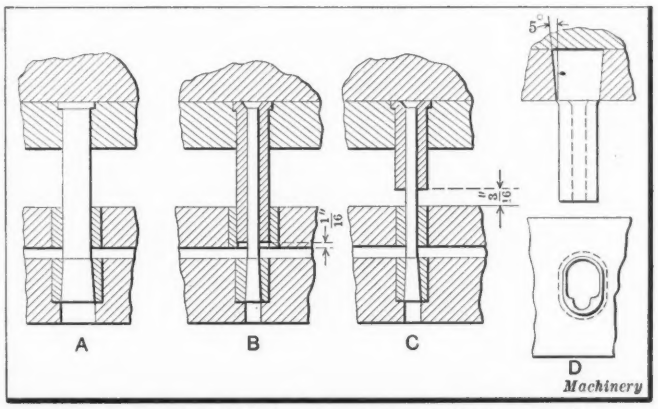


Fig. 1. Standard Methods of supporting Perforating Punches in Punch plates

IN many shops there is still a tendency to regard toolmaking as work on which it is inevitable for the labor charges to be high. Toolmakers who have learned their trade in such an atmosphere may be capable of doing very good work, but it is natural that they should have formed a habit of working slowly. Such men invariably run their machines at the slowest speeds and feeds, and as it is a foregone conclusion that the work will be expensive, no particular effort is made to devise ways and means of increasing the rate of production and making a corresponding reduction in cost. In the up-to-date tool-rooms of progressive manufacturing plants, all precedent is discarded in striving for increased efficiency. Necessarily there is a definite relation between the rate at which the work is produced and the accuracy of the product; but toolmaking methods have been carefully investigated with the view of increasing the output to the maximum that is consistent with the attainment of the required degree of accuracy.

Briefly speaking, this change in toolmaking practice has consisted of the introduction of manufacturing methods in the tool-room wherever such a course seemed feasible. An excellent example of this kind is seen in the system which has been developed by the Western Electric Co. for the production of all sizes of punches and dies which are used in this company's factory at Hawthorne, Ill. For example, in the case of tandem perforating and blanking dies, the use of six standard sizes has been adopted with the view of reducing the cost of production of these tools. Each size is designated by a number, and standard dimensions have been established for the die-block, stripper, die-holder, punch-holder, and punch-plate for each size of punch and die. The punch is made especially at the time that the order for any given punch and die is being filled, and the die-block is left soft ready to have a hole of the required shape cut in it. The use of standard sized hardened and ground dowel-pins, and standard round steel compression springs has also been adopted in punch and die work.

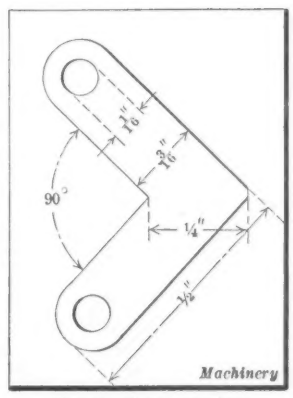


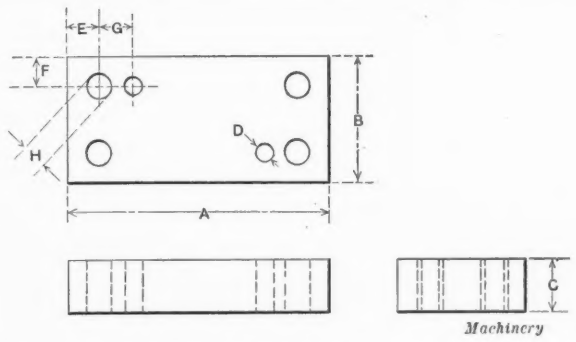
Fig. 2. Detail of Piece to be made

Increased efficiency of production is secured in several directions through the establishment of these punch and die standards. Most important among these is the fact that the adoption of uniform sizes insures the existence of a future demand for parts of the different standard sizes of punches and dies. As a result, these parts can be produced on a manufacturing basis, a series of each of the parts being made and delivered to the stock-room, where they are kept, pending the receipt of requisitions from the tool-room for the necessary number of parts to fill orders for punches and dies to be used in the various manufacturing departments. Needless to say, punches and dies can be produced far more economically in this way than would be possible in making individual parts for a given punch and die at the time the order was issued.

In addition to effecting a saving in the cost of labor for toolmaking, this method is also the means of making a noteworthy saving of labor in the drafting-room. When an order is received to design a punch and die for producing some new part, the draftsman's work is quite simple. All that he has to do is to make a detail drawing of the part to be produced and an assembly drawing of the punch and die to be used for its manufacture. The size-number of the standard punch and die to be employed is specified on the drawing, and the two drawings, when approved, are sent to the tool-room. The tool-room foreman then sends a requisition to the stock-room, calling for the standard parts that are required for producing this punch and die. It will be obvious that the punch must be made especially for the part which is to be produced, and it has already been mentioned that the standard die-block is sent to the stock-room in the annealed

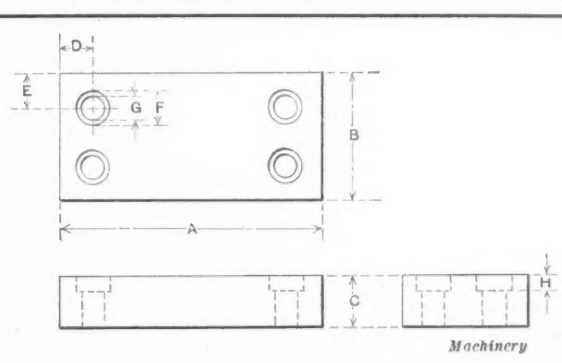
* Associate Editor of MACHINERY.

TABLE I. DESIGN AND DIMENSIONS OF STANDARD DIE-BLOCK



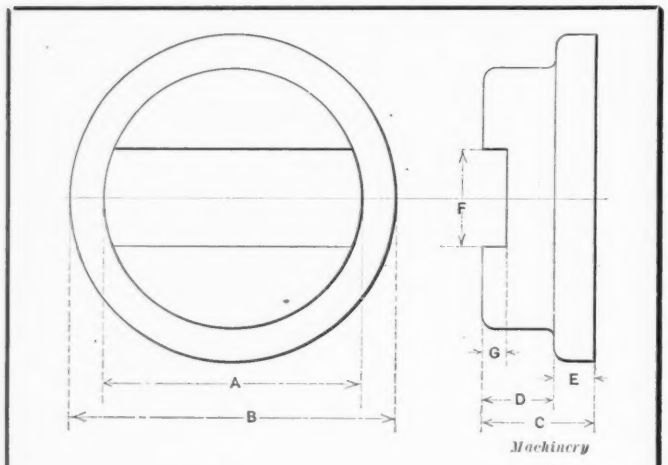
No. of Die-block	A	B	C	D		E	F	G	H
				Drill	Ream				
4	3	1½"	⅝"	15/64"	¼"	⅜"	⅜"	⅜"	9/32"
5	4	2	⅝	19/64	5/16	½	7/16	½	11/32
6	5	2½	⅝	23/64	⅜	½	½	½	13/32
8	7	3½	⅞	27/64	7/16	⅝	9/16	⅝	15/32
10	9	4½	1⅛	31/64	½	⅞	¾	⅞	17/32

TABLE II. DESIGN AND DIMENSIONS OF STANDARD STRIPPER-PLATE



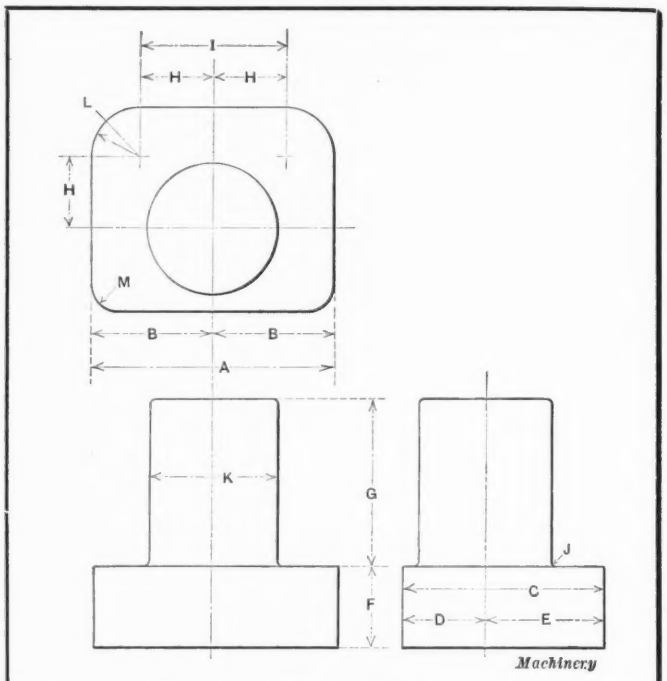
No. of Stripper	A	B	C	D	E	F	G	H
4	3"	1½"	½"	⅜"	⅜	0.353"	9/32"	5/32"
5	4	2	½	½	7/16	0.447	11/32	9/16
6	5	2½	⅝	⅝	½	0.510	13/32	¼
8	7	3½	⅝	⅝	9/16	0.572	15/32	¼
10	9	4½	⅝	⅞	¾	0.697	17/32	5/16

TABLE III. DESIGN AND DIMENSIONS OF STANDARD DIE-HOLDER



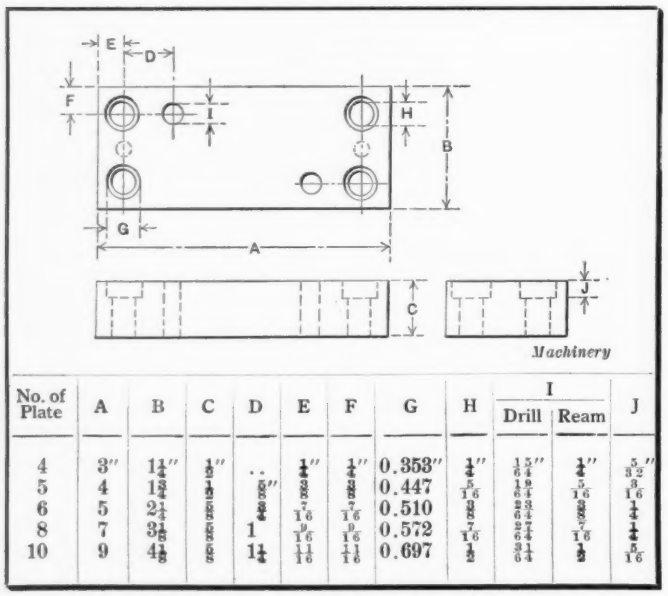
No. of Die-holder	A	B	C	D	E	F	G
4	4″	5″	$1\frac{3}{4}$″	$1\frac{1}{8}$″	5″	$1\frac{1}{2}$″	3″
5	5	6	$1\frac{3}{4}$	$1\frac{1}{8}$	5	2	3
6	6	7	$1\frac{3}{4}$	$1\frac{1}{8}$	5	$2\frac{1}{2}$	3
8	8	9	$2\frac{1}{4}$	$1\frac{5}{8}$	5	$3\frac{1}{4}$	3
10	10	11	$2\frac{1}{4}$	$1\frac{5}{8}$	5	$4\frac{1}{2}$	3
12	12	13	$2\frac{1}{2}$	$1\frac{7}{8}$	5	..	3

TABLE IV. DESIGN AND DIMENSIONS OF STANDARD PUNCH-HOLDER



Holder No. of Punch	A	B	C	D	E	F	G	H	I	J	K	L	M
4	$3\frac{3}{4}$″	$1\frac{7}{8}$″	$3\frac{1}{8}$″	$1\frac{1}{4}$″	$1\frac{7}{8}$″	1″	$2\frac{1}{2}$″	$1\frac{1}{8}$″	$2\frac{1}{4}$″	$\frac{1}{8}$″	2″	$\frac{3}{4}$″	$\frac{1}{4}$″
5	$4\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{4}$	1	$2\frac{1}{2}$	$1\frac{7}{16}$	$2\frac{7}{8}$	$\frac{1}{8}$	2	$\frac{13}{16}$	$\frac{1}{4}$
6	$5\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{2}$	$\frac{1}{8}$	2	1	$\frac{1}{4}$
8	$7\frac{1}{4}$	$3\frac{5}{8}$	$5\frac{1}{2}$	$1\frac{7}{8}$	$3\frac{5}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$4\frac{3}{4}$	$\frac{1}{8}$	2	$1\frac{1}{4}$	$\frac{1}{4}$
10	9	$4\frac{1}{2}$	7	$2\frac{1}{8}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$	3	6	$\frac{1}{8}$	2	$1\frac{1}{2}$	$\frac{1}{4}$
12	$10\frac{5}{8}$	$5\frac{5}{16}$	$8\frac{1}{16}$	$2\frac{3}{4}$	$5\frac{5}{16}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	7	$\frac{1}{8}$	2	$1\frac{13}{16}$	$\frac{1}{4}$

TABLE V. DESIGN AND DIMENSIONS OF STANDARD PUNCH-PLATE



No. of Plate	A	B	C	D	E	F	G	H	I Drill	I Ream	J
4	3″	$1\frac{1}{4}$″	$\frac{1}{2}$″	..	$\frac{1}{4}$″	$\frac{1}{4}$″	0.353″	$\frac{1}{4}$″	$\frac{15}{64}$″	$\frac{1}{4}$″	$\frac{5}{32}$″
5	4	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$″	$\frac{5}{16}$	$\frac{5}{16}$	0.447	$\frac{5}{16}$	$\frac{19}{64}$	$\frac{5}{16}$	$\frac{3}{16}$
6	5	$2\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	0.510	$\frac{3}{8}$	$\frac{23}{64}$	$\frac{3}{8}$	$\frac{1}{4}$
8	7	$3\frac{1}{8}$	$\frac{5}{8}$	1	$\frac{9}{16}$	$\frac{9}{16}$	0.572	$\frac{7}{16}$	$\frac{27}{64}$	$\frac{7}{16}$	$\frac{1}{4}$
10	9	$4\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{11}{16}$	$\frac{11}{16}$	0.697	$\frac{1}{2}$	$\frac{31}{64}$	$\frac{1}{2}$	$\frac{5}{16}$

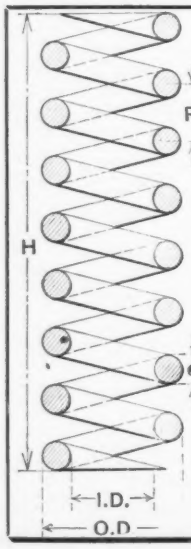
Note.—Dotted circles show dowel-pins in punch-plate No. 4

TABLE VI. DIMENSIONS OF STANDARD DOWEL PINS

No. of Dowel Pin	Diameter	Length	Make from
1	$\frac{3}{16}$″	$\frac{7}{8}$″	No. 8 drill rod (0.197 inch)..
2	$\frac{3}{16}$	$1\frac{1}{8}$	No. 8 drill rod (0.197 inch)..
3	$\frac{1}{4}$	1	No. G drill rod (0.261 inch).
4	$\frac{1}{4}$	$1\frac{1}{4}$	No. G drill rod (0.261 inch).
5	$\frac{5}{16}$	$1\frac{1}{4}$	No. P drill rod (0.323 inch).
6	$\frac{5}{16}$	$1\frac{1}{4}$	No. P drill rod (0.323 inch).
7	$\frac{3}{8}$	$1\frac{1}{8}$	No. W drill rod (0.386 inch).
8	$\frac{3}{8}$	$2\frac{1}{8}$	No. W drill rod (0.386 inch).
9	$\frac{7}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$-inch tool steel..... ....
10	$\frac{7}{16}$	$2\frac{3}{8}$	$\frac{1}{2}$-inch tool steel.....
11	$\frac{1}{2}$	$2\frac{3}{4}$	$\frac{9}{16}$-inch tool steel.....

Machinery

TABLE VII. STANDARD COMPRESSION SPRINGS FOR USE IN PUNCH AND DIE CONSTRUCTION

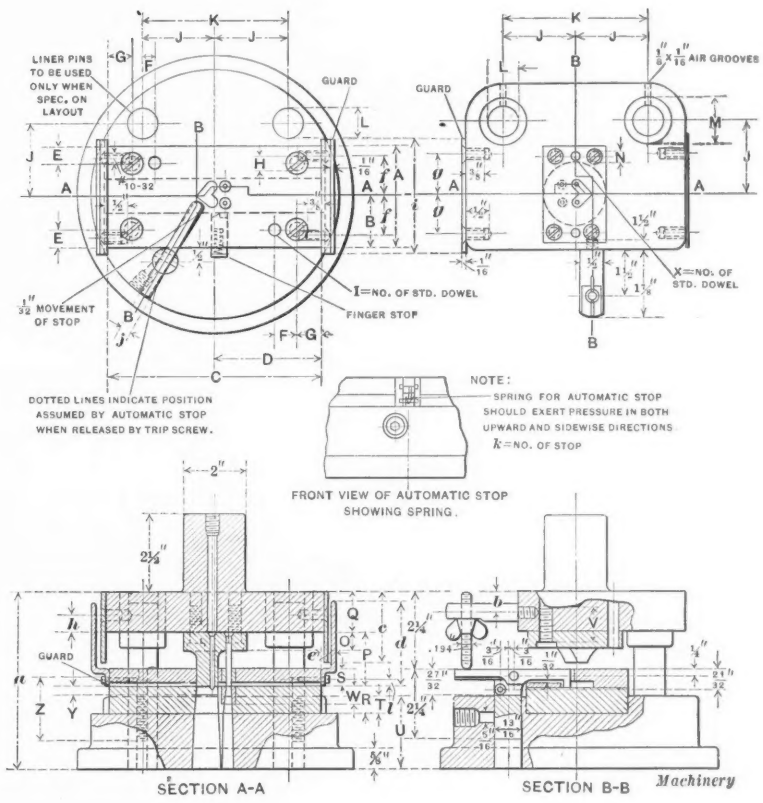


O. D.	I. D.	d	P	H	Max. F per in.	Max. W	F per In. W=100 Lbs.	W F=0.1 inch per in.	O. D.	I. D.	d	P	H	Max. F per in.	Max. W	F per in. W=100 Lbs.	W F=0.1 inch per in.
In.	In.	In.	In.	In.	In.	Lbs.	In.	Lbs.	In.	In.	In.	In.	In.	In.	Lbs.	In.	Lbs.
$\frac{7}{32}$	0.153	0.032	0.057	3	0.3995	515	0.25740	0.0137	$\frac{51}{64}$	0.347	0.225	0.350	$1\frac{3}{4}$	0.0869	626	0.01400	0.0721
$\frac{7}{32}$	0.124	0.063	0.110	36	0.1055	42	0.25182	0.0396	$\frac{51}{64}$	0.347	0.225	0.350	$5\frac{7}{8}$	0.0869	626	0.01400	0.0721
$\frac{3}{8}$	0.135	0.120	0.198	36	0.0576	213	0.02677	0.0370	$\frac{13}{16}$	0.429	0.192	0.300	2	0.1399	358	0.03906	0.0256
$\frac{21}{64}$	0.213	0.120	0.198	$1\frac{1}{4}$	0.0980	163	0.06010	0.0166	$\frac{53}{64}$	0.340	0.244	0.369	$1\frac{3}{4}$	0.0794	781	0.01003	0.0985
$\frac{1}{2}$	0.260	0.120	0.198	$1\frac{1}{4}$	0.1273	143	0.08888	0.0113	$\frac{61}{64}$	0.465	0.244	0.369	6	0.1168	644	0.01816	0.0550
$\frac{1}{2}$	0.176	0.162	0.256	36	0.0578	395	0.01445	0.0686	$1\frac{1}{4}$	0.636	0.307	0.463	$3\frac{1}{2}$	0.1309	964	0.01361	0.0736
$\frac{17}{32}$	0.207	0.162	0.256	$1\frac{1}{2}$	0.0688	362	0.01914	0.0527	$1\frac{1}{4}$	0.636	0.307	0.463	5	0.1309	964	0.01361	0.0736
$\frac{9}{16}$	0.266	0.148	0.242	$2\frac{5}{8}$	0.1004	246	0.04091	0.0244	$1\frac{1}{4}$	0.390	0.430	0.555	$3\frac{1}{8}$	0.0589	3046	0.00198	0.5162
$\frac{5}{8}$	0.385	0.120	0.183	$1\frac{1}{4}$	0.2432	107	0.22723	0.0044	$1\frac{3}{8}$	0.761	0.307	0.495	$6\frac{5}{8}$	0.1572	851	0.01838	0.0540
$\frac{5}{8}$	0.385	0.120	0.183	$1\frac{3}{4}$	0.2432	107	0.22723	0.0044	$1\frac{7}{16}$	0.713	0.362	0.550	$4\frac{1}{2}$	0.1218	1385	0.00875	0.1139
$\frac{5}{8}$	0.301	0.162	0.256	$1\frac{1}{2}$	0.1082	288	0.03750	0.0266	$1\frac{1}{2}$	0.776	0.362	0.550	6	0.1362	1309	0.01036	0.0963
$\frac{21}{64}$	0.257	0.192	0.286	$1\frac{3}{4}$	0.0766	496	0.01538	0.0646	$1\frac{5}{8}$		$\frac{5}{8}$	0.500	0.750	$6\frac{1}{8}$	0.0707	3491	0.00200	0.4935
$\frac{11}{16}$	0.237	0.225	0.319	36	0.0624	774	0.00815	0.1241	$2\frac{1}{32}$	$1\frac{1}{32}$	0.500	0.688	$7\frac{1}{2}$	0.1427	2565	0.00552	0.1796
$\frac{25}{32}$	0.331	0.225	0.319	36	0.0903	643	0.01411	0.0711	$3\frac{1}{2}$	2	0.750	1.000	12	0.2111	4820	0.00440	0.2280
..	....	.....	.....	....	.....	....	.....	.....	$3\frac{1}{2}$	$1\frac{3}{4}$	0.875	1.063	18	0.1551	8018	0.00198	0.5116

Machinery

NOTE: F=compression in spring; W=load on spring; For other notations see diagram.

TABLE VIII. LAYOUT FOR PERFORATING AND BLANKING PUNCH AND DIE


LINER PINS TO BE USED ONLY WHEN SPEC. ON LAYOUT
GUARD
GUARD
1/8" X 1/16" AIR GROOVES
10-32
1/32" MOVEMENT OF STOP
I=NO. OF STD. DOWEL
FINGER STOP
X=NO. OF STD. DOWEL
DOTTED LINES INDICATE POSITION ASSUMED BY AUTOMATIC STOP WHEN RELEASED BY TRIP SCREW.
NOTE:
SPRING FOR AUTOMATIC STOP SHOULD EXERT PRESSURE IN BOTH UPWARD AND SIDEWISE DIRECTIONS
K=NO. OF STOP
FRONT VIEW OF AUTOMATIC STOP SHOWING SPRING.
GUARD
SECTION A-A
SECTION B-B
Machinery

No. of Punch and Die	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
4	1½"	¾"	3"	1½"	⅜"	⅜"	⅜"	¼"–20	4	1 1/8"	2¼"	½"	13/16"	10"–32	½"	1½"	1 "	⅝"	½"
5	2	1	4	2	7/16	½	½	5/16 –18	6	1 7/16	2⅞	1		12 –24	½	1½	1	⅝	½
6	2½	1¼	5	2½	½	⅝	⅝	⅜ –16	8	1¾	3½	¾	1 1/8	¼ –20	⅝	1¾	1¼	⅞	⅝
8	3¼	1⅝	7	3½	9/16	¾	⅞	7/16 –14	10	2⅜	4¼	1	1 1/2	5/16 –18	⅝	1¾	1¼	⅞	⅝
10	4½	2¼	9	4½	⅝	⅞	1	½ –13	11	3	6	1¼	1¾	⅜ –16	⅝	1½	1¼	1⅛	⅝
12	..	..	..	..	..	..	..	.....	..	3½	7	1½	2⅛	7/16 –14	⅝	..	..	..	..

No. of Punch and Die	T	U	V	W	X	Y	Z	a	b	c	d	e	f	g	h	i	j	k	l
4	⅜"	1¾"	1 "	7/16"	1	¼ "	1½"	4½"	½ "	1¾"	2¼"	17/32"	½"	⅞"	½"	2½"	7/32"	1	¼"
5	⅜	1¾	1	7/16	3	¼	1½	4½	½	1¾	2¼	17/32	¾	⅞	½	2½	7/32	1	¼
6	⅜	1¾	1¼	½	5	5/16	1¾	5⅛	⅝	2⅛	2¾	13/32	1	1⅛	⅝	3	9/32	2	5/16
8	½	2¼	1¼	⅝	7	5/16	2	5⅝	⅝	2⅛	2¾	9/32	1⅛	1½	⅝	3¼	9/32	2	5/16
10	⅝	2¼	1¼	¾	9	⅜	2¼	5⅞	⅝	2⅛	2¾	5/32	2	2⅛	⅝	5	9/32	2	5/16
12	..	2½	..	..	..	..	..	..	..	..	..	..	..	2⅝	⅝	5½	..	..	..

condition, so that it is ready to have the hole machined in it. After this work has been done, the punch and die are hardened and the entire tool may then be assembled.

In connection with the design of perforating punches and dies, standard methods have been adopted for holding the punches in the punch-plate, these standard constructions being shown in Fig. 1. All punches made of larger sections than No. 1 drill rod are strong enough to do without a supporting sleeve, and the standard construction for such punches is shown at *A*. For small punches where a supporting sleeve is required, the standard construction is shown at *B*, where it will be seen that the supporting sleeve slides in a bushing carried in the stripper-plate. In some cases, however, the form of bushing shown at *B* occupies too much space, and where the amount of available room for the bushing in the stripper-plate is limited, the form of construction shown at *C* has been adopted. At *D* is shown the method of holding punches which must be sheared into the die. Reference to the illustration will show that the punch is provided with a 5-degree taper shank which supports it securely in the punch-plate.

As an example of the way in which this system works out, consider the case of making a tandem perforating and blanking punch and die for producing the part, Fig. 2. Ribbon stock is used for this purpose, and the assembly drawing of the punch and die is shown at the top of Table VIII. Reference to this illustration will show that the tool is provided with a pair of perforating punches for piercing the two holes in the work, and a blanking punch for stamping out the finished part from the stock. At each stroke one finished part is produced, while the perforating punches make the two holes in the part which will be stamped out from the stock by the following stroke of the press. It will be seen that the assembly drawing gives the toolmaker complete instructions, and with the standard parts of the punch and die in stock ready for use, the work of making the tool is a matter of simple routine and can be handled very rapidly.

Toolmakers will doubtless be interested in the materials which are specified by the Western Electric Co. for making the standard parts for the type of tandem perforating and blanking dies which has been referred to. The punch-plates are made of machine steel, the carbon content of which must not exceed 0.20 per cent. These parts are completely finished, including the screw and dowel-pin holes. The punch-holders and die-holders are made of cast iron, and they are finished ready for use. The stripper-plates are made of machine steel with a carbon content of not over 0.20 per cent. The screw holes are machined at the time the stripper-plates are made, while the dowel-pin holes are transferred from the die-block at the time the die is made up. The die-blocks are, of course, made of tool steel, with the screw and dowel-pin holes and all surfaces finished ready for use. The stock for making dowel-pins is given in Table VI.

The "suggestion box" idea is used in the Hawthorne shops of the Western Electric Co., with the view of encouraging employes to hand in written suggestions regarding ideas for the improvement of manufacturing methods. One employe suggested making dowel-pins which were 0.001 inch over size, for use in cases where the dowel-pin holes in the die-block had been lapped too large. One of the rules in connection with the operation of the "suggestion box" is that a report shall be sent to the employe, either accepting his idea or giving the reason for its rejection. The dowel-pin idea was turned down, because it was felt that the stocking of these over-size dowel-pins would tend to create a spirit of carelessness on the part of the toolmakers, which would be very undesirable. Furthermore, if the plan of carrying special parts of this character in stock were adopted, an excessive amount of storage capacity would be required.

It has been the purpose of this article to describe a principle of toolmaking rather than to give specific information on the making of punches and dies. The tables give the sizes which the Western Electric Co. has found satisfactory for use in making tandem perforating and blanking punches and dies. The Western Electric Co. has also developed standards for sub-press dies and other classes of dies, which enable the same economies to be taken advantage of; but it is not within the scope of this article to give detailed information in regard to the dimensions of the different sizes of tools in these classes. The sizes would necessarily vary with the character of the work, and manufacturers would therefore be able to adopt standards that are best suited to their requirements.

* * *

RECENT LEGAL DECISIONS INVOLVING MACHINERY

Patent Infringements

(Federal) The making of what is a single part in a patented machine in two pieces does not avoid infringement, where they do the same work as the single piece in substantially the same manner. The United States Circuit Court of Appeals has so held in Stockland v. Russell Grader Mfg. Co. The Russell Grader Co. was the owner of a patent for certain improvements in a road grading machine. Defendant Stockland built a similar machine, but containing more parts to it. The question was whether this second machine infringed the first. The court in holding the Russell Grader Mfg. Co. to be infringed said: "In determining the question of infringement, the court or jury, as the case may be, are not to judge about similarities or differences by the names of things, but are to look at the machines or their several devices or elements in the light of what they do, or what office or function they perform, and how they perform it, and to find that one thing is substantially the same as another, if it performs substantially the same function in substantially the same way to obtain the same result, always bearing in mind that devices in a patented machine are different in the sense of patent law when they perform different functions in a different way, or produce a substantially different result, * * * as it is necessary in every such investigation to look at the mode of operation or the way the device works, and at the result, as well as at the means by which the result is attained. Inquiries of this kind are often attended with difficulty; but if special attention is given to such portions of a given device as really do the work, so as not to give undue importance to other parts of the same which are only used as a convenient mode of constructing the entire device, the difficulty attending the investigation will be greatly diminished, if not entirely overcome." Damages were awarded to the Russell Co. *(Stockland v. Russell Grader Mfg. Co., 222 Fed. 906.)*

Use Not Essential to Maintenance of Patent

(Federal) Machines which, although patented, were not practically operative and were abandoned after slight use, are not anticipations which will invalidate a subsequent patent for an operative and successful machine. In a suit by the Benthall Machine Co. v. National Machine Corporation, the Benthall Co. charged the National Corporation with having made and sold machines for picking peanuts from vines which infringed its patents. The defense of the National Corporation was that the Benthall Co.'s patent was impractical and inoperative and had been discarded after slight use, and that the National Corporation had improved and changed the machine so that it became a machine which was practical and operative. The United States District Court at Norfolk, Va., having jurisdiction of the case, held the National Corporation's machine to be an infringement of the Benthall patent. The court said that non-use of a machine would not affect the legal rights of the patentee to enjoy the monopoly given it by virtue of the patent. *(Benthall Machine Co. v. National Machine Corporation, 222 Fed. 931.)*

Negligent Operation of Machinery

(Pennsylvania) Where, in an employe's action for injuries from being caught in a moving sprocket of a machine which plaintiff was adjusting, it appeared that the guard had been removed from the sprocket to change the machinery, and that before making the adjustment plaintiff had been ordered by the foreman to replace the guard, but had failed to do so, plaintiff was guilty of contributory negligence barring his right to recover. *(Peiper v. Reading Iron Co., 94 A. 745.)*

Defective Appliances

(Pennsylvania) Where, in an employe's action for injuries from the breaking of a machine, causing a load to fall and crush plaintiff's fingers, there was evidence that the broken link had not been properly welded, and that the imperfect welding would have been discovered by a proper inspection, the court properly affirmed a point to the effect that such a defect was a structural defect of which the employer is presumed to have knowledge. *(Case v. Lehigh Coal & Navigation Co., 94 A 253.)*

Merger of Corporations

(New Jersey) Under New Jersey corporation laws providing that any two corporations organized under the laws of the state to carry on any kind of business of the same or a similar nature may merge into a single corporation, which may be either one of them, or into a new corporation, a corporation whose charter authorized it to construct bridges, buildings, machinery, electric works, waterworks, canals, and other means of transportation, and to sell or otherwise dispose of or to maintain and operate the same, and whose specified objects and powers were declared to be in no way limited by reference to or inference from the terms of any other clause of the certificate, in some of its objects was not similar to any of those of a corporation chartered with the primary object of manufacturing, selling, leasing, and dealing in machinery of every kind, and especially shoe machinery, so that the two could not be merged. *(Copeland v. United Shoe Machinery Co., 94 A. 405.)*

Remedy of Sellers

(Connecticut) Where a contract for the sale of a machine contained a written promise by the buyer to pay therefor within 30 days, and a printed clause reserving title in the seller until payment was made, and providing that in case of rejection the property should be returned within 30 days or the objection thereto would be waived, the printed clause, when construed in harmony with the buyer's promise to pay, gives him only the right to reject for good cause, not to reject at will. A contract of sale which provides that in case of failure to pay in installments the whole contract price shall become due and payable and the seller shall have the right to retake the property and retain it or resell it, gives the seller an option to retake the property or to recover the price. *(United Machinery Co. v. Metzel & Sons, 94 A 355.)*

The Return of Defective Machinery

(Kentucky) If a purchaser of machinery, upon ascertaining that it fails to fulfill the conditions of the contract as to amount and quality of work it can turn out, wishes to cancel the contract or hold the seller liable for breach thereof, he must, within a reasonable time, offer to return the machinery and rescind the contract.

The time within which a purchaser of machinery found to be defective must return it and rescind the contract of sale may be extended by promises on the part of the seller to repair, and by its insistence that the purchaser keep the machinery and give him an opportunity to make it do the agreed work. What is a reasonable time for a purchaser of machinery to return it and rescind the contract for defects in the machinery depends upon the facts of the particular case. *(Meek Coal Co. v. George D. Whitcomb Co., 176 S. W. 854.)*

Unguarded Machinery

(Missouri) The operator of a wood-working machine, while attempting to adjust a defective and rapidly revolving drill, reached around the saw on the same shaft in order to pick up a screwdriver with which to throw off the belt. His hand was caught by the saw, which was not guarded as required by Kansas law. Held, that plaintiff was not guilty of contributory negligence as a matter of law, either by placing the screwdriver where he did, or in attempting to adjust the drill without stopping the machinery. *(Hughes v. D. E. Marshall Contracting & Mfg. Co., 176 S. W. 534.)*

WHAT'S THE MATTER WITH THE FOUNDRIES?

BY J. P. BROPHY*

Undoubtedly, thousands of people who have more or less to do with foundries will claim that there is nothing the matter with them, but from experience—and some of it really costly—I must say that there is much the matter with many of the foundries in this country at this time, and there has been right along. I maintain that as far as the quality of castings is concerned the foundries are not one particle better than they were twenty or more years ago. There is just as much uncertainty now as to what you might expect from your patterns from so-called first-class foundries as there was a quarter of a century ago. Many will perhaps take exception to this positive statement, but it is based on bitter experience.

Poor castings are detrimental in two ways. The one who receives them and does more or less work on them perhaps discovers in the last operation that there is a blow-hole or a dirty spot in some section, and the consequence is that he generally loses the labor expended. More than this, in many instances it sets back the producing power of his plant, because a number of inferior castings coming in quantities, of which you perhaps have none in stock, means that all the operations of setting up and machining are wasted.

The foundry likewise suffers a loss of the castings, and in some cases inferior castings are charged back to them, and any one would think that the foundries would try to find out, scientifically or otherwise, what is the matter and why so many poor castings are returned to them every day.

All lines of manufacturing have advanced wonderfully until at present in many large plants the loss from poor work is a minimum. Much has been written about the great strides foundries have made in producing castings. Nevertheless, they are slow to grasp or slow to be able to improve to the extent of being able to anywhere nearly guarantee that if you order fifty castings from one pound to one thousand pounds they will be practically all the same and usable.

The foundry business seems to be a somewhat mysterious proposition. The pattern is placed in the sand, all the work performed to complete the mold, the iron is poured in and no one knows for a certainty what the result will be. I don't pretend by any means to understand the foundry business, but there is negligence somewhere that certainly should be rectified.

The producing of small castings by the use of machinery and otherwise has perhaps reached the maximum in the foundry, but when it comes to quality, uncertainty prevails in all directions. If it is because of inferior sand being used or inferior ramming of the mold, or inferior venting or anything inferior in the labor in preparing the flask for the metal to be poured, why is it that with all the experience the foundrymen have had for a generation they have not been able to discover where the trouble lies and are not able to say for a certainty what the results are going to be?

When returning inferior castings to the foundries, either before or after work has been performed on them, they take it as a matter of course and seem to expect a considerable portion of their castings to be returned. If you send in a complaint, there is a possibility that the foundry foreman will visit you and talk matters over, but from past experience you feel almost certain that all this talk is a waste of time, for the reason that they do not seem to be able to improve in producing their product.

If a pattern is sent to a foundry today (and it makes no difference what foundry it might be) which is cored considerably, you can feel quite certain that the cores will either be set in the wrong position or something will happen to this casting—perhaps two or three times—before you finally obtain the results that can be obtained after a great many have been made. In any other line of business it is not expected that anything like this will occur. For this reason it might well be asked: "What's the matter with the foundries?"

Many large foundries would be ahead thousands of dollars a year in net earnings if the castings they produced came anywhere near a fair percentage in soundness. It is a common occurrence to find a large blow-hole hidden in a casting that does not show up in the manufacturing, but under strains after it has left your plant and reached the customer breakage takes place and you are condemned, whereas it is impossible for you to discover this particular blow-hole or weakness in your own plant.

Is it possible that the foundries are careless in mixing their iron before placing it in their cupola? Is it not possible that the iron is not brought to the proper temperature before being poured? Is it not possible that the gates where the metal travels to its destination are in the wrong position—too small or too large—is there something wrong with this part of the foundry business?

Many foundries are exceptionally negligent in their mixture of iron—there is no question about this. Many times you pay for what you don't get. Cast iron should be of a standard tensile strength, at least in the machine tool business, and when 20 per cent steel is used there should be a standard for this also. The writer has known of cases where 20 per cent steel was asked for, and in analyzing no steel could be discovered at all, but an inferior grade of ordinary cast iron. This shows that some foundries are exceptionally careless, or else wilfully accept money that doesn't belong to them. To be anywhere nearly sure of what you are receiving, it seems necessary to analyze each lot of castings to determine their quality.

Up to this point this talk has been on ordinary gray iron. The same might be said of steel castings. No dependence can be placed on steel castings. You never know what you are getting. The writer has attempted to use steel castings for cams and spur gears and obtained these castings from various foundries. In the rough they look fairly good, but after being machined they show up their weaknesses. There is no question but that the steel casting business is just as far behind as it was twenty years ago.

We read considerable about this line of business also, and according to articles about same it has reached the highest pinnacle of perfection. This argument might be considered O. K. if you used rough castings and the patterns were large enough to stand for weaknesses here and there owing to inferior metal, but when the casting must be machined then you will discover that the steel casting business seems to be only in its infancy, and that the producers are not thoroughly posted as to what they are capable of doing. This may appear to be a somewhat severe criticism but there is no guesswork on the part of the writer. Experience has been the teacher in this case.

Consider malleable iron also. We do not seem to have any improvement on this line of goods. It seems to be made in the same old way. There is no telling, for a certainty, what you are going to receive. If tested for tensile strength you will discover that it varies in all directions. I have known of many cases where the foundries wanted greater length of time to produce castings. They explained that they required to dry their molds out thoroughly, but even after this was done the results were just the same as explained in this article—a real game of chance.

Another source of considerable trouble is the fact that you never know when you have a fair size casting made, weighing say 1000 to 1500 pounds, and your pattern is ⅜ inch thick, whether your casting will be ½ inch or ¾ inch thick. You certainly cannot depend upon the foundries to produce castings of the same thickness as your patterns. This is either carelessness in rapping the pattern before removing it from the mold, or in giving you over-weight castings. Many times when a casting should actually weigh 1000 pounds it will come 1200 or 1300 pounds. This is inexcusable, but it seems almost impossible to defend yourself against it.

Regardless of the kind of castings being made, large or small, the metal in many cases is poured from one cupola, and you take what you get and let it go at that. In the writer's estimation it seems that any good foundry should have a number of cupolas with various mixtures to suit the requirements of the various castings they are producing.

* Vice-president and general manager, Cleveland Automatic Machine Co., Cleveland, Ohio.

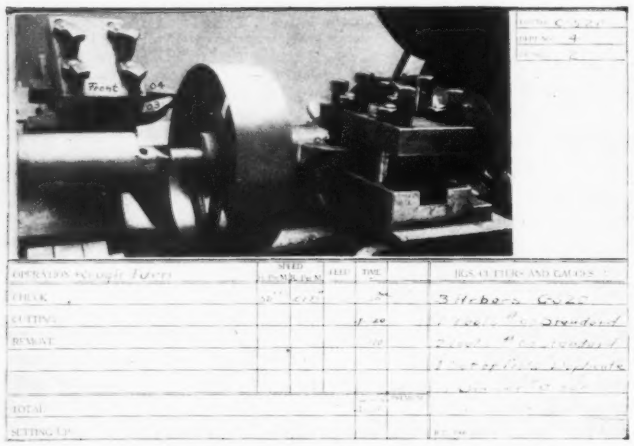


Fig. 1. Shop Operation Sheet for rough-turning a Pulley

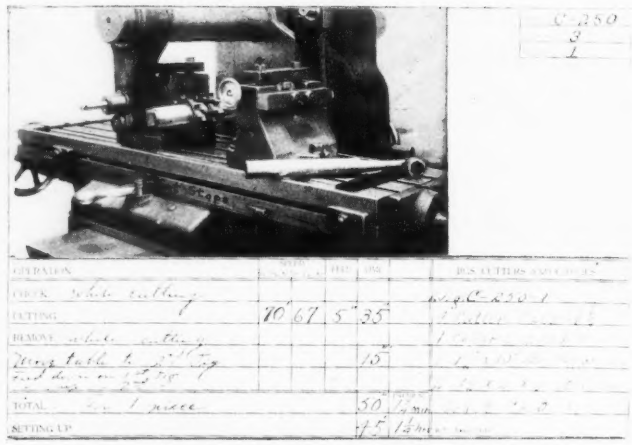


Fig. 2. Shop Operation Sheet for Milling Machine Job

PHOTOGRAPHIC SHOP OPERATION SHEETS

The accompanying illustrations show a method for making shop operation sheets used by the Jones & Lamson Machine Co., Springfield, Vt. Figs. 1 and 2 show the photographs and instructions mounted on cardboard, as given to the machine operator, while Figs. 3 and 4 show the shop operation sheets or records retained by the efficiency department and filed away for future reference. As shown, the machine operator is given a photograph of the proposed method of setting up the machine for a given job, and on the same sheet instructions are given as to the speed and feed to use and the time required for the job. The object of the photograph is to record accurately the tools to be used, how they are used, what clamps and holding-down screws are used, and to show clearly all special arbors and fixtures. The photograph is superior to a drawing, especially when used by more or less unskilled operators. In general, it is far easier for the shop man to set up work in a machine from a photograph than from a drawing.

In order to determine the proper speeds and feeds and the time required, the work is first done in a special department, which determines what methods are to be used. The job is started at a speed which experience has shown to be as rapid as possible for the work in hand. Ten pieces are made and the operations timed. No time of less than a second is considered, and usually on a job of several minutes duration, the time is taken to the nearest multiple of five seconds. Apart from this brief explanation, the shop operation sheets speak for themselves. Sometimes reference letters are marked with ink on the photographs, in order to more clearly indicate the requirements to the operator. The illustrations shown have been furnished through the courtesy of F. E. Lockwood, in charge of the efficiency department of the Jones & Lamson Machine Co.

* * *

Elimination of waste and saving labor are cardinal principles of efficiency; they make for greater comfort and higher standards of living for all. Some of our institutions have applied the principle of eliminating waste and saving with remarkable results. A well-known Cleveland hotel provides ice water on draft in the guest rooms besides hot and cold water. The annoyance of summoning a bell-boy to fetch it is avoided. An automatic switch extinguishes the electric light when a guest leaves his room, the action of locking the door on the outside actuating the switch. The same action is reversed when the door is unlocked, the lights going on as the door is opened. Thus the guest has the comfort of going into a fully lighted room but the management is not burdened by the waste of electricity uselessly consumed while the guest is not occupying his room.

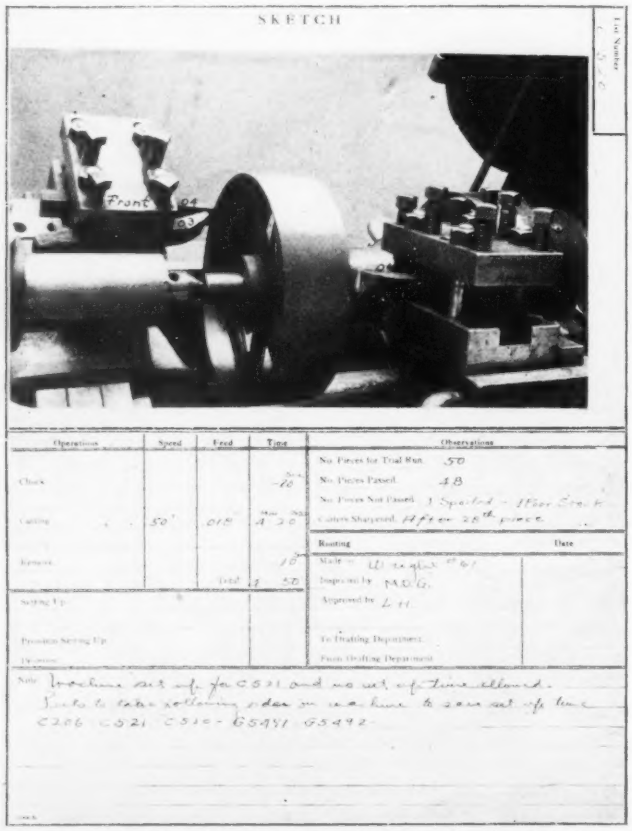


Fig. 3. Efficiency Department Record of Operation Sheet Fig. 1

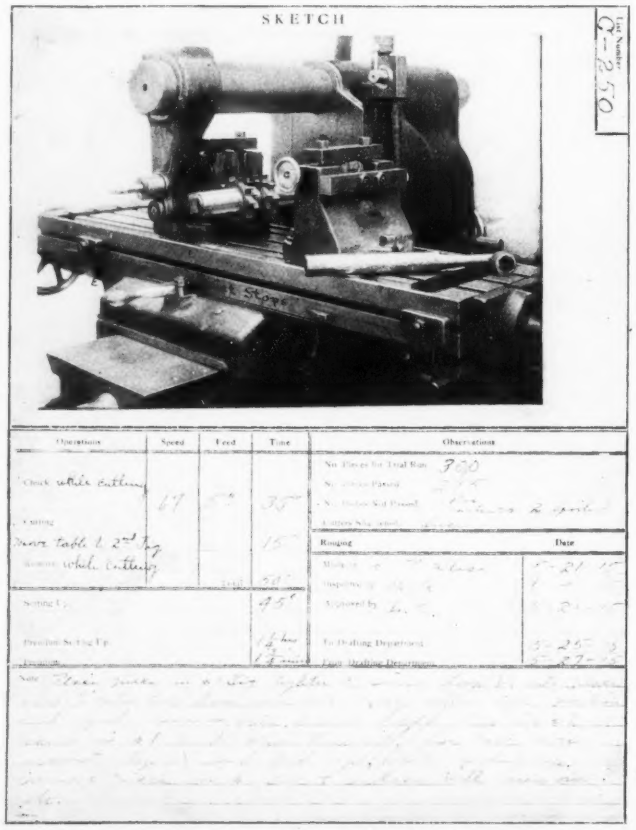


Fig. 4. Record preserved of Operation in Fig. 2

CHECKING DRAWINGS—HOW AND WHY

BY CHARLES F. SCRIBNER*

When the activity of your drafting room has increased so that you employ ten times as many men as heretofore, unless your chief draftsman has organized his department in a systematic manner for the handling of the increased volume of work, his hair will soon turn grey with worry and deep furrows will line his once placid brow. If his system of checking has been such that each man has been required to check his own work, the new order of things will mean not ten times the previous number of errors—in some cases it will mean ten times ten. It is a hard matter to make such an enlargement to a drafting room without getting a certain percentage of unskilled and careless men, especially when all your competitors are making the same change.

Under these conditions a factory that was recently called upon to make such additions to its normally small force of men in the drafting room, decided to adopt a system of checking all drawings that would eliminate, as far as possible, the chances of errors being passed along to the factory; and that would enable the responsibility for errors found in the shop to be placed upon the proper employes. Several men who had been employed for some time in the drafting room were chosen to act as checkers, and were supplied with blueprint copies of the following checking list. This list had been typed on thin bond paper, using a sheet of carbon paper reversed against its back, so that good clear prints were obtained. The checkers were also supplied with complete lists of "standards," as were all draftsmen, and they had access to the pattern index files so that stock patterns would be used wherever possible. In checking, items were taken up according to number, so as to avoid skipping any item which might later give trouble. The checking list follows:

Standard Instruction Sheet No. 84.

March 22, 1915.

From: Engineer-In-Charge,
To: Checkers, Drafting Room.
Subject: CHECKING DRAWINGS.

Beginning today, all drawings will be checked for errors in accordance with the following list. Check the drawing for Item 1, then for Item 2, etc. Don't skip around—by so doing, you may make a costly mistake.

1. Is the size of sheet correct?
2. Is the title, scale, drawing number, model, number required, etc., correctly given?
3. Is there a sufficient number of views to correctly show the piece?
4. Are all views detailed in third-angle projection?
5. Are full and dotted lines shown in their proper places?
6. Are dimensions properly located?
7. Are views shown correctly as to right and left hand? Are even numbers used for right-hand patterns and odd numbers for left-hand?
8. Is the design correct in principle?
9. Is it what is needed and can nothing better be suggested? Can it be made cheaper?
10. Is the drawing correct to scale, and are those dimensions not scaling correctly underlined?
11. Are arrow-heads neatly and properly shown?
12. Is all necessary information given, and are all dimensions "tied up"?
13. Are all dimensions given in decimals, except where fractions are necessary?
14. Are tapped holes shown correctly?
15. Are "f" marks shown where needed?
16. Is the proper draft provided for all patterns and forging dies?
17. Are all corners provided with rounds or fillets?
18. Is a note given in regard to counterboring or other finish for screw heads?
19. Are all bosses large enough?
20. Are all parts of proper strength?
21. Are detail notes provided regarding heat-treatment, polishing, electro-plating, etc.? Are such notes correct?
22. Are parts marked "grind," where needed?
23. Are all given dimensions correctly figured?
24. Will the piece properly fit parts with which it is to be assembled, and will it work without interference?
25. Is clearance provided for wrenches and screw-drivers?
26. Is there clearance provided to allow for all variations and tolerances?
27. Are proper oil-holes provided, and is there a sufficient number of them?
28. Are all parts provided with a sufficient number of threads of proper pitch for the material used?
29. Is the allowance for driving and running fits expressed in thousandths of an inch, and are the parts marked with their plus and minus limits?
30. Are developed lengths of parts shown?
31. Are all parts "necked" to provide clearance for the wheel when grinding?
32. Is provision made on all drill jigs, fixtures, etc., for the removal of burrs and chips?
33. Constructive changes: Note position, relation, diameter, length, thickness, width and bearing on prior effective changes.
34. Has proper consideration been given to the subsequent attachment of other parts?
35. Is the material cross-sectioned according to standards?
36. Has the following information been given regarding springs: Temper, gage number and decimal diameter of wire, number of coils, initial tension, inside diameter and length in compression?
37. Is it shown on dies where they are to be ground?
38. Is relief provided on the corners in casement fits?
39. Is clearance provided for the leaf swing on jigs and fixtures?
40. Can the bosses shown be drawn from the sand?
41. If two dowel pins are used, is one shorter than the other so that one can enter before the other?
42. Are all male fillets from 1/16 to 1 inch provided with a plus radius of 1/16 inch and from 1 to 2 inches with a plus radius of ⅛ inch?
43. Are you willing to stand responsible for any errors noted above, if this drawing is sent into the factory?
44. Have you signed this drawing as "checked?"

* * *

THE SWEDISH ENGINEERING CONVENTION IN THE UNITED STATES

The first Swedish Engineering Convention in the United States was held at the La Salle Hotel, Chicago, September 9, 10, and 11, and was attended by over two hundred engineers of Swedish extraction, both from Sweden and from all parts of the United States. Owing to the disturbed conditions in Europe, the delegation from Sweden was very much smaller than had been originally expected, only fifteen engineers from that country having braved the present dangers of the sea to come to the United States. Papers were read by J. Körner, of Vesteras, Sweden, on "The Industries of Sweden and their Forms of Organization;" by F. Sandelin, of Sandviken, Sweden, on "The Natural Resources and Future Industrial Possibilities of Sweden;" by A. G. Witting, of the Indiana Steel Co., Gary, Ind., on "The Uses of the By-products of the Steel Industry;" and by A. Engblom, of Shelton, Conn., on "Scientific Management and its Practical Applications." Excursions were made to the Gary Steel Works, the Pullman Car Works, the Western Electric Co., and the Union Stock Yards. The convention was very successful as regards the exchange of ideas of an engineering nature and also from a social point of view in that it brought together a great number of engineers who had known each other in the past years but who have been scattered all over the United States. It was proposed to make the convention organization a permanent one and to hold similar conventions at certain intervals in the future, alternately in Sweden and in the United States. The holding of a convention of this kind, at this time, is especially significant, as the United States and Sweden are at present the only two nations of any industrial importance that are at peace with each other and the rest of the world.

* * *

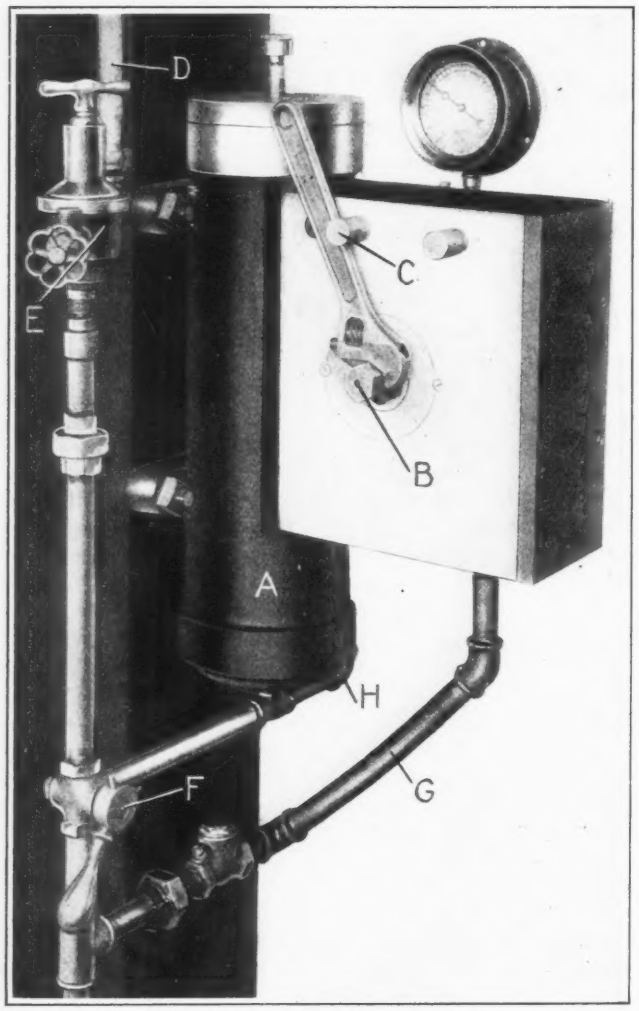
The first calculating machine invented was made by Pascal, the eminent French mathematician, about 1641. He was not only one of the foremost mathematicians in his day but also excelled in mechanics. The next notable production in this field was made by Leibnitz, about 1671. He made several multiplying and dividing machines, and one constructed about 1700 is still in existence. In some of its features, this machine resembled the Thomas machine which was built and marketed one hundred and twenty years later, improved types of which are still in use.

* Address: P. O. Box 556, Hartford, Conn.

A HYDRAULIC WRENCH TESTING DEVICE

At the factory of the Crescent Tool Co., Jamestown, N. Y., manufacturer of wrenches and similar tools, there is in operation an apparatus for wrench testing that is of interest because few tool manufacturers subject wrenches to an actual gage test before being sent into service. This apparatus is shown in the accompanying illustration, and the principle upon which it operates includes the engaging of the wrench jaws by a central stud that is turned by hydraulic pressure until a predetermined pressure has been applied to the wrench.

The apparatus is mounted upon a post, and consists of a cast-iron cylinder *A*, within which is a piston carrying a rack that meshes with a spur gear keyed to stud *B* over which the wrench jaws fit. As the handle of the wrench is prevented from turning through contact with a pin *C*, it



How "Crescent" Wrenches are tested

is obvious that the continued rising of the piston and consequent turning of stud *B* places the same strain upon the wrench that it would receive in actual service. The piston is hydraulically operated, and the supply pipe through which water pressure enters is shown at *D*. The water passes through a reducing valve *E*, that can be set to different pressures for the different sized wrenches, so that only enough pressure will be turned on to test the particular type of wrench that is going through. At *F* is a three-way valve. When this valve is open the pressure through the supply pipe comes down and around into the cylinder, forces the piston up, and through the rack and pinion, causes the stud to turn and thus places a strain on the wrench. Drain pipe *H* allows the water in the cylinder to be let out after the testing action has taken place and the plunger is free to return to its normal position. A continuation of the supply pipe turns the corner at *G* and runs up to the pressure gage shown above the testing block. This indicates at all times the amount of pressure being applied to the wrench. Valve *E* may be set so that this pressure will not exceed a predetermined amount. In drain pipe *G* is a check valve whose function it is to keep the back pressure from entering the apparatus.

With this apparatus the Crescent Tool Co. is enabled to test various sized wrenches with a surety that the tools that leave the factory have passed a test as severe as any they will receive in service. C. L. L.

* * *

GIVE AND TAKE

Modern manufacturing methods have in many cases reduced the cost of products so low that further reductions seem hardly worth striving for, unless corresponding reductions in selling costs can be effected. The great problem of the day is to secure more efficient means of distribution. Improved machinery is offered for sale to all alike, and concerns in competing lines using standard machinery are brought to an even footing as regards facilities for manufacturing, provided their capital is sufficient to provide for the equipment needs. Plant management, first-class material and selling efficiency are what count in the game of competition.

The modern manager is keenly alive to the importance of keeping up to date by reading the technical journals in his field, and some subscribe to these publications for their foremen. In view of this eager desire for knowledge and keen appreciation of that gained from other sources it seems unwisely selfish to maintain a semi-closed shop policy, but many do. An editor visiting one of these plants may be courteously received and shown through, but he must promise not to print anything about what he saw. Knowledge is broadening and the technical editor gladly avails himself of every opportunity to see what is going on in all shops within his field, but he also wishes to make such excursions profitable to the larger circle of his readers.

The funny part is that visiting courtesies are often extended to men, who, unknown to the proprietor, have connections with competitors. They get the details in a more or less accurate way and use them to their own advantage, when their own factory practice is behind the times. The ostrich who hides his head in the sand, thinking thereby he is safe from annoyance, is not more self-deceived than many of the smartest men acting in the capacities of general managers of industrial plants.

* * *

CHEMICAL ENGINEERING DEPARTMENT OF COLUMBIA UNIVERSITY

Columbia University has established a separate department of chemical engineering upon the same plane of importance as mining, civil, electrical and mechanical engineering in recognition of the tremendous development of our chemical industries that is bound to take place because of the European war. The sudden demand for products previously secured from Europe has greatly stimulated activity among chemical manufacturers. In many cases, it is necessary first to develop the raw material supplies, as for example in the manufacture of coal tar dyes, where large quantities of benzol, phenol, toluol, etc. are required. The demand for these materials is being met by the installation of large plants for the recovery from coke oven gases of these heretofore waste products. Such concerns as the Lackawanna Steel Co., United States Steel Co. and other large coke producers, both in the United States and Canada, are now recovering these products. Similar activity has developed in other fields, the large demand for explosives having enormously increased the production of sulphuric and nitric acids. Entirely aside from these abnormal developments, forced upon us by the war, it should be noted that important chemical processes are being established in other fields. Recently, two enormous installations, one at the Anaconda Smelter and another at Chuquicamata, Chile, have been started for the extraction of copper by chemical methods. Plants for the production of sulphuric acid from the roasting of sulphide ores have also been established.

LETTERS ON PRACTICAL SUBJECTS

We pay only for articles published exclusively in MACHINERY

WHAT IS VANADIUM STEEL?

Some time ago a concern in which the writer is interested placed an order with a steel foundry located somewhat less than 100 miles from the Chicago postoffice for the following:

> Six tray lips, pattern A-1044. These lips are to be of vanadium cast steel 0.35 to 0.45 carbon, annealed. Care should be taken that the metal in the cutting edges is solid and of the best quality.

These castings were shipped direct to a coal dock where they were to be used. Some of them broke within a few hours and all within a comparatively short time after being put into service, and did not last as long as some ordinary open-hearth steel tray lips which had previously been used. Payment of the bills was refused and the steel foundry brought suit in which the following testimony was developed.

The superintendent of the steel foundry testified that 6½ pounds vanadium (alloy about one-third pure) was used in each pot of 1600 pounds steel, which would amount to 0.15 to 0.16 per cent (calculation shows 0.1354 per cent) and in reply to a question regarding standard vanadium stated that vanadium *put in* castings varies from 0.05 to 0.15 per cent—sometimes higher if it is ordered higher; also that the amount of ferro-vanadium lost in the melt varies a good deal with the temperature of the steel, from *nothing up to one-half of one per cent.*

A chemist testifying for the defendant stated that he found the vanadium content of the castings, defendant's exhibits 1 and 2, to be 0.03 and 0.04 per cent; carbon content 0.375 and 0.384 per cent.

A metallurgist of twenty-eight years active experience, the last six years devoted especially to vanadium alloys, testifying for the defendant, stated that if 6½ pounds of ferro-vanadium (33 1/3 per cent vanadium) were added to 1600 pounds of steel, it would be equivalent in round numbers to 0.14 per cent vanadium, and that there would be at least 20 per cent and possibly 30 per cent of that lost. The result would be about 0.10 per cent in round numbers of vanadium remaining in the steel. He further stated *that there is a recognized standard vanadium steel,* containing not less than 0.15 per cent vanadium, and that castings containing only 0.03 and 0.04 per cent would not be castings of standard vanadium steel, and that the two castings—defendant's exhibits 1 and 2—showed numerous gas cavities and blow-holes.

Three other witnesses testifying for the defendant stated that after the castings were broken they observed numerous holes, variously designated by them as air-holes, blow-holes, sand-holes, etc., and specified various sizes up to an inch—a little larger—a little smaller.

The attorney for the plaintiff stated verbally, "When you specified vanadium as you did in the contract, *you left it entirely to us,* to our judgment, as to the amount of vanadium to be put in," and, in his brief stated, "We submit that if there is a 'standard,' under the contract the plaintiff was not required to furnish it, and that if it was required to do so, it did furnish steel substantially complying with the alleged standard specifications as disclosed by the record." (R. W. Hunt & Co.'s analysis as testified to above shows vanadium 0.03 to 0.04 per cent.)

The Encyclopædia Britannica, Vol. 14, page 812 says, "Vanadium in small quantities (0.15 or 0.20 per cent) is said to improve steel greatly, especially in increasing its resistance to shock and to oft-repeated stresses."

Notwithstanding the above testimony as to vanadium content and defects in castings, a decision was given for the plaintiff.

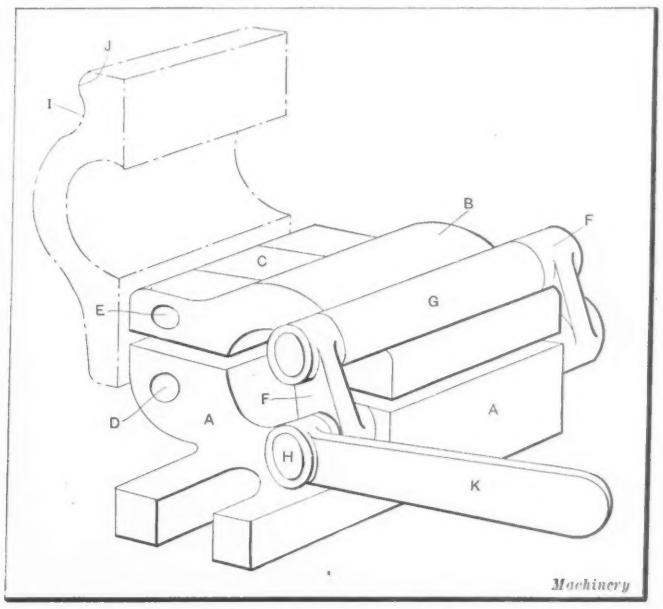
The question now comes up, which interests all purchasers of steel castings of special alloy or otherwise: "Is there a standard vanadium steel casting, and to what extent must full and complete specifications, chemical as well as physical, be given in a simple order when not covered by a term contract in which these elements are covered?"

Let the steel foundries come forward and declare themselves. Would all of them make the claim put forward by the attorney for the plaintiff in the above case, and would they, under the circumstances, claim that these were merchantable castings? What is the opinion of the trade on this subject?

Chicago, Ill. D. J. EVANS

ECONOMICAL FIXTURE DESIGN

When laying out jigs or fixtures for handling a variety of similar classes of work, it is economical to design the parts in such a way that many of them can be made in duplicate. This allows the same patterns to be employed and enables the machining operations to be conducted more efficiently.

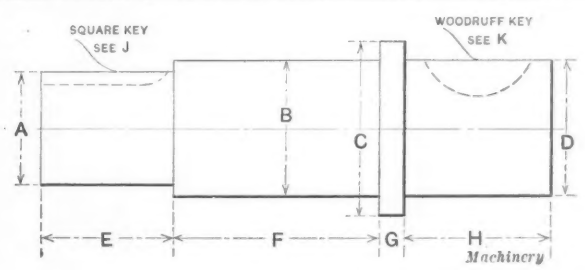


Design of Standard Fixture for Use in milling Keyseats in Spindles of the Dimensions shown in the Table

For example, let us assume that the spindle shown at the top of the accompanying table is to be made in three standard sizes, the dimensions of the different sizes being given in the table. In designing a spindle-clamping fixture for holding this work for milling the keyways, a little study would enable many of the parts of the fixture to be standardized, thus reducing the cost of producing them to a minimum.

A fixture that may be used for holding the spindle for milling the keyways is shown in the accompanying illustration.

DIMENSIONS OF STUD USED IN KEYSEAT MILLING FIXTURE



A	B	C	D	E	F	G	H	J	K
1	1 1/4	1 7/8	1 1/4	1 1/4	2 1/4	3/16	1 7/8	1/4 Sq.	No. 18
1 1/4	1 9/16	2	1 5/16	1 5/8	2 5/8	1/4	2	5/16 "	" 23
1 1/2	1 7/8	2 1/4	1 7/8	2	3 1/16	1/4	2 1/4	5/16 "	" 23

Machinery

This may be briefly described as follows: The base *A* of the fixture, which is bolted to the milling machine table, has a cap *B* connected to it by means of a link *C* and bearing pins *D* and *E*, the arrangement being such that the cap *B* may be swung up to provide for removing finished work from the fixture. The ends of the pin *H* are eccentric to that portion of the pin which has a bearing in the base of the fixture, the amount of eccentricity being sufficient to allow the clamping bar *G* to swing out of the groove *I* and over the curved section *J* as the handle *K* is raised to a vertical position. This allows the cap *B* to be raised to the position shown by the dotted lines, to provide for setting up the work.

To make this fixture so that it will accommodate the three sizes of spindles dimensioned in the table, to enable the parts to be manufactured in duplicate and simplify the pattern work, is what may properly be termed "economical tool design." It has been found possible to make in duplicate the link *C*, link pins *D* and *E*, links *F*, clamping bar *G*, eccentric *H*, and handle *K*. In laying out the base *A* and cap *B*, the length of the bearings should not be more than 2¼ inches, which is the minimum dimension *F* in the table. The diameter of the bore for the three sizes of spindles would be 1¼, 1 9/16 and 1⅞ inch, respectively. This requires that the thickness of the metal shall be sufficient to provide strength for holding the spindle of 1⅞ inch diameter, and also that the core shall be small enough for the spindle of 1¼ inch diameter. Care given to these details will not only save money in making the fixtures, but it will also result in a saving of the space required for storing and listing duplicate tool patterns.

Brookline, Mass. ARTHUR B. BABBITT

A USE FOR AN OLD SLIDE-RULE

Many men have an old slide-rule that is so worn or warped that it is no longer useful for its original purpose. In almost every drafting room there are one or more such slide-rules knocking about. The scales on these rules can be used to excellent advantage as logarithmic scales for use in making graphical analysis of problems in machine design, and for many other purposes. This is done by simply taking the rule apart and beveling the edges of the wood under the scales, as shown in Fig. 1. With an ordinary Mannheim slide-rule the writer prefers to bevel the under side of the *A* scale, where large work is to be handled; while in the case of small diagrams, the *C* scale is very satisfactory. As these rules are generally made of straight grained wood, it is an easy matter to bevel the edges with a small plane or even with a pocket knife.

Another use that these scales can often be put to is in preparing tables or diagrams of weights of certain parts of complete machines. An example is shown in Fig. 2, where one curve of a diagram of the weights of cast-iron pulleys of a given diameter and of various face widths, is presented. Of course, the complete diagram shows a large number of curves for pulleys of different diameters, but for the sake of simplifying the chart for reproduction, the curve for only one of these diameters is shown. In this case, it was desired to illustrate the weight of these pulleys within a small percentage of the actual weight, this percentage of error being the same for all sizes of pulleys. A table covering all sizes of pulleys which can be shown on such a chart would have filled several pages of a salesman's book, and such tables would have required a lot of time to calculate. By making a rough sketch of a pulley and calculating the necessary dimensions for the allowable stresses for each of four widths for each diameter, it was possible to draw curves through the four points so determined. The weights of the remaining twelve pulleys of each diameter could then be found on these curves, as accurately as the commercial practice requires.

Birmingham, Ala. FREDERICK W. SALMON

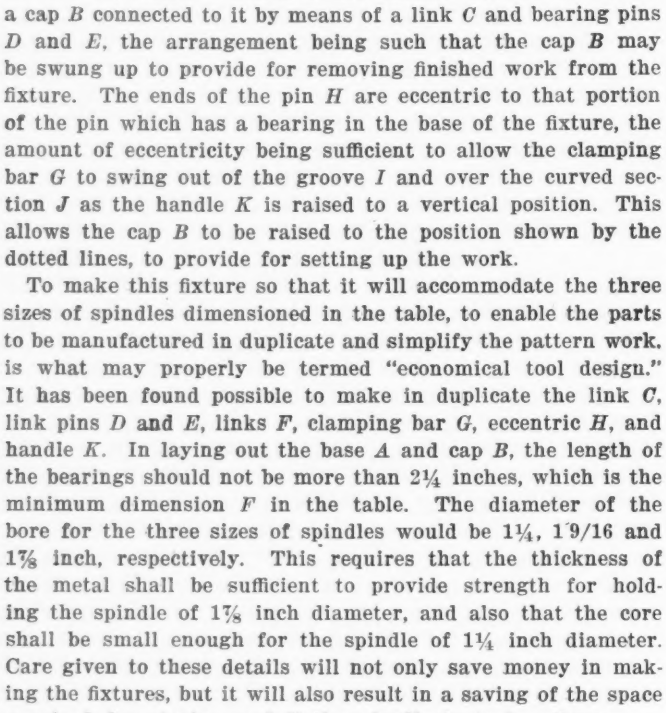


Fig. 1. Logarithmic Scales made from Worn-out Slide-rule

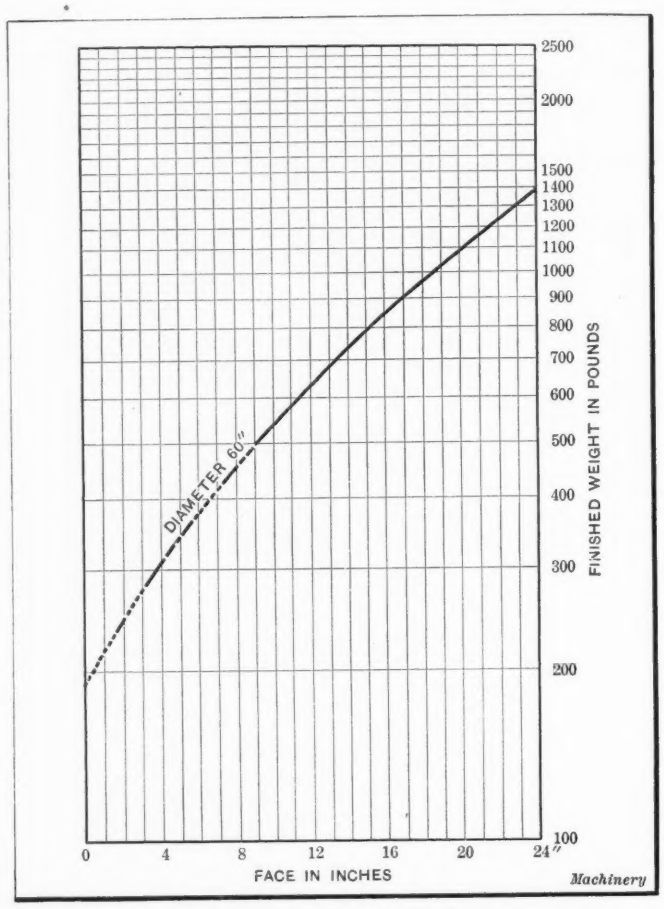
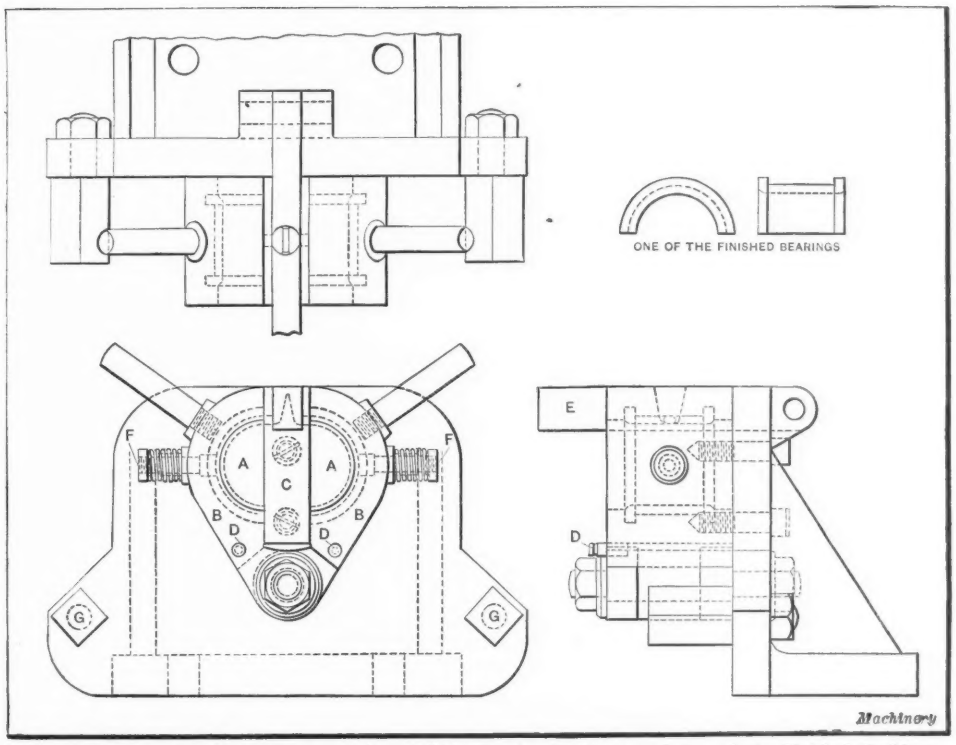


Fig. 2. An Example of Use of Logarithmic Scales shown in Fig. 1

BABBITT BEARING MOLD

In the December and March numbers of MACHINERY, descriptions were published of molds for making babbitt bearing bushings. After reading these descriptions, the writer is inclined to believe that the mold which forms the subject of the present article is more efficient than either of the two previously described. The first cost is no greater and it appears that this mold could be operated more rapidly and that it would be longer lived.

Referring to the accompanying illustration, it will be seen that the main casting or frame consists of an angle block on which the cores or half-arbors *A* are mounted. The molds *B* are made of cast iron and are pivoted on a shoulder bolt at the bottom of the steel center piece *C*. The molds are operated by the handles at the top and are held against the center piece by a spring which extends across between the pins *D*. When the mold is open, this spring passes below the center of the hinge pin and serves to hold



Improved Type of Mold for Use in casting Babbitt Bearing Bushings, and One of the Finished Bushings

the two halves of the mold apart. The pouring is done through a hole in the center piece *E* which is hinged at the back of the angle block; and a tapered pouring hole connects with the molds through two small holes in the center piece *C*.

After the bushings have been poured, the center piece *E* is driven up with a light lead hammer, and in so doing cuts off the babbitt sprues extending into the holes in the center piece *C*. At the same time this jars the bushings loose. The piece of babbitt which is left in the center piece *E* drops out due to the tapered opening. The mold is then opened by means of the two handles, and the ejecting pins *F* strike the posts *G*. The movement of the ejecting pins is limited by collars on the stems, being just sufficient to force the bushings out of the molds. There is, of course, a small projection of babbitt left on one side of each bushing, but this is easily removed on the disk grinder or by filing. When the mold is again closed, the springs on the ejector pins push them back to their proper positions. When the mold is open, the halves are in a nearly horizontal position so that they are easily inspected or cleaned. The entire apparatus is bolted to a bench when in use.

D. S. Mann

SHALL WE USE WIDE OR NARROW GUIDES?

The accompanying illustration shows the saddle of a machine tool sliding on the guiding surfaces *S* and propelled by a force *F* which overcomes the resistance *R* due to the tool carried on the saddle, etc. To simplify the following discussion, the propelling force *F* and the external resistance *R* have both been shown in a plane passing through the center line of the guiding surfaces *S*. Assuming the surfaces *T* to be frictionless and that the normal pressure *N* is concentrated at the ends of the saddle, we have:

$$Nf = G$$

where f = coefficient of friction;

G = frictional resistance at the ends of the saddle where they slide upon the surfaces *S*.

The total moment *M* about the line of action of the propelling force *F* due to the resistance overcome is as follows:

$$M = NfA + NfD + RB \quad (1)$$

In order to have the mechanism in equilibrium, the moment of the reaction of the guiding surfaces *S* must equal *M*. Hence we have:

$$M = NL \quad (2)$$

By equating Formulas (1) and (2) we obtain the following expression:

$$N = \frac{RB}{L - fA - fD} \quad (3)$$

As the propelling force must equal the resistance overcome, we have:

$$F = R + 2Nf \quad (4)$$

Solving Formula (4) for the value of *N*, we obtain:

$$N = \frac{F - R}{2f} \quad (5)$$

Then by equating Formulas (3) and (5) we find the following value of *F*:

$$F = R + \frac{RB}{\frac{L}{2f} - \frac{A + D}{2}} \quad (6)$$

By an inspection of the illustration we find that the distance *C* from the line of action of the force *F* to the center line between the guiding surfaces *S* has a value of $\frac{A + D}{2}$. Substituting this value in Equation (6), we have:

$$F = R + \frac{RB}{\frac{L}{2f} - C} \quad (7)$$

$$F = R\left[1 + \frac{B}{\frac{L}{2f} - C}\right] \quad (8)$$

By an inspection of Formula (8), bearing in mind that the surfaces *T* have been considered frictionless, and also that the inertia due to the weight of the saddle has been neglected, we reach the following conclusions: First, as the width of the guides does not enter into the equation, it does not affect the force required to propel the saddle over the guides. Second, other conditions being fixed, the value of the propelling force *F* is a minimum: (1) When the distance *C* is zero; (2) When the distance *B* is zero; (3) When the distance *L* is infinite; (4) When the value of *f* is zero. Third, other conditions being fixed, the value of the propelling force *F* is infinite, or in other words the guide is self-locking, when the distance *C* is equal to $L \div 2f$.

Kenmore, N. Y. Sherwood C. Bliss

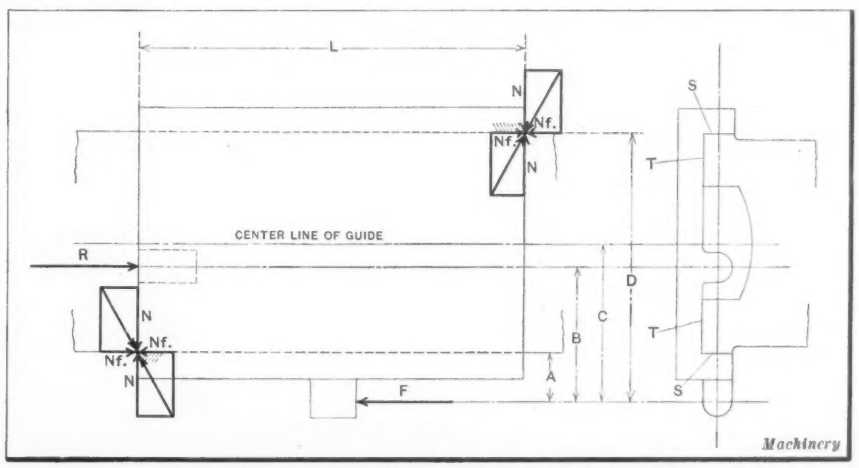


Diagram showing Principal Forces acting on Saddle and Guides of Machine Tool

DRAFTING-ROOM KINKS WHICH ELIMINATE SHOP ERRORS

A drawing is the best and clearest method of conveying an idea to a workman, but it is highly important for all drawings to be made so explicit that they cannot be misunderstood. It is the purpose of this article to explain one or two simple "kinks" which have been found useful in eliminating certain mistakes that are sometimes made by the mechanic who has not had a great deal of experience in "reading drawings."

Fig. 1 is a reproduction of a drawing of a small machine steel block on which the surfaces which are to be finished by grinding are marked with a letter G. As these surfaces are not too clearly indicated, it is not uncommon for the grinding operation to be omitted. Another somewhat common error on this job is for the man who orders the stock to use his own judgment when ordering material instead of following

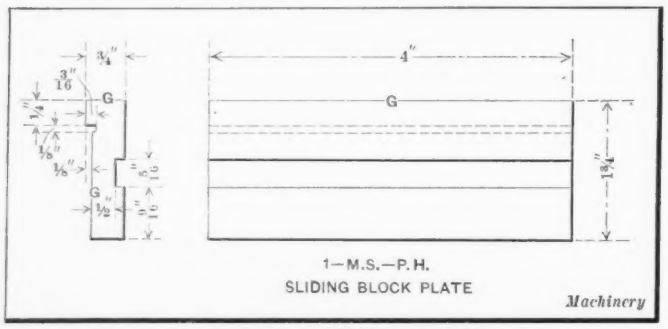


Fig. 1. Shop Drawing of a Machine Steel Block to be finished by Grinding

the drawing. Fig. 2 shows the same drawing in which these two items of the shop instructions are brought forcibly to the mechanic's attention by employing arrows as "tell-tales" which call attention to the notes concerning the method of finishing the work and the material to use.

Another source of annoyance for which there is no real necessity is the obscure way in which the identification numbers are often placed on drawings. As the number is the point looked for in locating a given drawing, it should be made quite conspicuous, and this is done in Figs. 3 and 4 by putting the number in the upper right-hand corner where it is readily seen. A similar source of trouble arises when the arrow points indicating the termination of dimension lines on drawings are so faint on blueprints that they are not readily discernible. Where the dimension lines are made continuous, as shown in Fig. 3, it is sometimes very hard to tell from what points they extend. By staggering them, as shown in Fig. 4, much of the trouble from this source is overcome.

F. SERVER

CONFLICT OF ONE-HALF-INCH THREAD PITCHES

Does it not seem strange that in these days of efficiency systems and all the rest of the modern requirements tending toward high-speed production, two pitches of thread for the half-inch diameter screw should be tolerated? The U. S. standard pitch for the half-inch screw is thirteen threads per

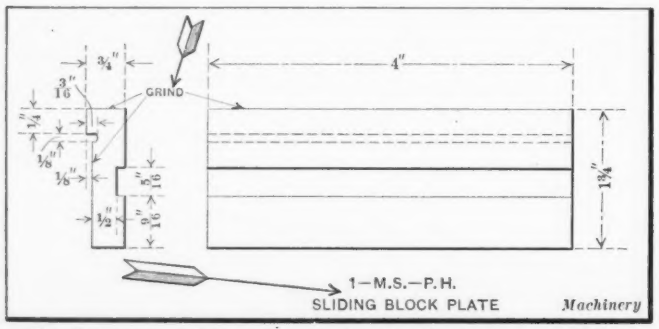


Fig. 2. Drawing of Part shown in Fig. 1 with Arrows to emphasize Material and Finish Notations

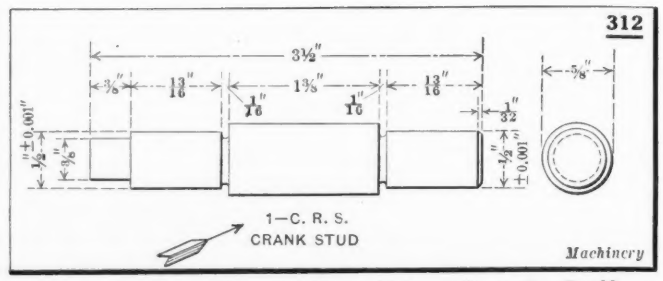


Fig. 3. Continuous Dimension Lines which sometimes give Trouble on Indistinct Blueprints

inch, and yet the market is supplied with screws having both twelve and thirteen threads per inch. In the shops where the writer is employed, the half-inch machine bolts and headless set-screws used have thirteen threads per inch while cap-screws and common set-screws have twelve threads. In case it is desired to change from one kind of set-screw to the other after a hole has been threaded, the thread has to be practically ruined to effect the change.

Other standard screw sizes show no such conflict of pitches, and there seems to be no good reason why there should be two pitches in common use for the half-inch screw. Of course, if the purchasing agent specifies when ordering that all bolts, cap-screws, studs, set-screws and nuts, should be of a certain pitch, he would probably be supplied with what he orders, and so confusion in that particular shop would be prevented. But what does the average purchasing agent know about such things? The proper ones to remedy the fault would seem to be the manufacturers; they should adhere to the established standard pitch for the half-inch screw as they do for all others. This matter would seem to be of sufficient importance to require attention and action—the sooner the better.

Los Angeles, Cal. JOHN A. WOOD.

[The condition described by Mr. Wood is one that has long existed, and it has caused endless trouble and confusion. It is true that thirteen threads to the inch is the Sellers or U. S. standard, but perhaps the founders of this standard made a mistake in using thirteen threads to the inch instead of twelve. The standard boiler thread is twelve threads per inch for all sizes, and of course a half-inch boiler stud or cap-screw is not an exception to the rule. Perhaps it would

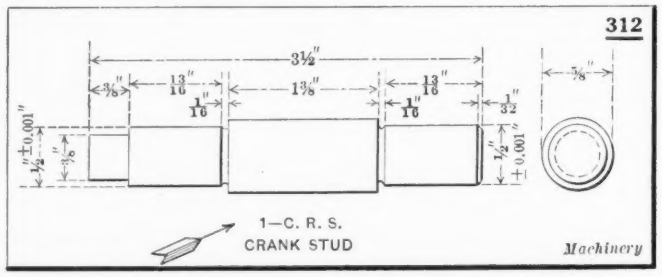


Fig. 4. By staggering Dimension Lines as shown in this Illustration, they stand out more clearly

have been wiser on the part of those who formulated the Sellers standard to have sacrificed an ideal number of threads in the case of the half-inch screw and made it the same as the boiler standard which had long been in use. Some of the largest manufacturers have clung to the half-inch twelve threads standard, notably the Westinghouse Air Brake Co. Notwithstanding the fact that the railroads generally have adopted the U. S. standard system, the Westinghouse Air Brake Co. has continued to make its half-inch studs and cap-screws with twelve threads per inch. The trouble incident to this double standard in railroad shops is typical of the condition generally existing where the two standards are used side by side.—EDITOR.]

* * *

Reinforced concrete is so rapidly coming into general use that figures relating to bridges of this construction are of unusual interest. The Walnut Lane Bridge has a span of 233 feet; at Grafton, New Zealand, there is a bridge with a span of 320 feet; over the Tiber, at Rome, 328 feet; and at Largweiz, Switzerland, 330 feet.

NEW MACHINERY AND TOOLS

THE COMPLETE MONTHLY RECORD OF NEW DESIGNS AND IMPROVEMENTS
IN AMERICAN METAL-WORKING MACHINERY AND TOOLS

NATIONAL-ACME SINGLE AND MULTIPLE DRILLING MACHINES

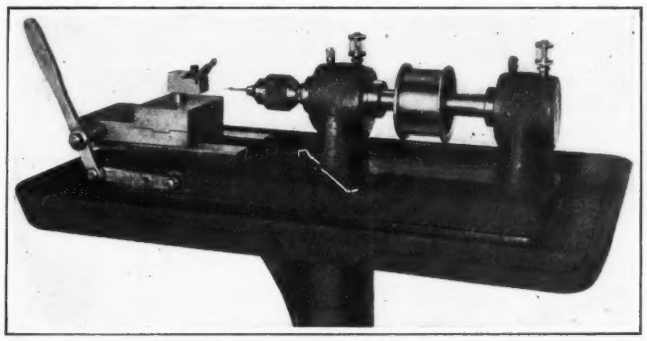


Fig. 1. National-Acme Style D Single-spindle Drilling Machine

The following description explains the essential features of a line of machines developed for performing such second operations as drilling, facing and counterboring on automatic screw machine product. It will be seen from the illustrations that the first two machines are of essentially the same design, with the exception that one has a single spindle while the other has two opposed spindles. These machines are for use in drilling one piece of work at a time. The third machine of the line is equipped with four spindles and a three-faced turret, so that four pieces of work can be drilled at a time; and the product can be removed from the fixtures and fresh blanks set up in place on two faces of the turret while the drilling operation is being performed on the work held in fixtures of the third turret face. The fourth machine is provided with six spindles and a compound slide on which the work-holding fixtures are carried. This slide enables either of the six alternate fixtures to be brought into line with the spindles so that the drilling operation can be performed on the work held in these six fixtures; and at the same time, the product can be removed from the other six fixtures and fresh blanks set up in place for the next drilling operation.

In the manufacture of screw machine parts in large quantities, the expeditious performance of such second operations as drilling, facing and counterboring is of vital importance. For handling such operations on the product after it has left the automatic screw machine, the National-Acme Mfg. Co., Cleveland, Ohio, has developed a complete line of single- and multiple-spindle drilling machines, the design of which includes some particularly interesting features. One of these machines of the single-spindle type, which is known as Style D, is shown in Fig. 1. It has a maximum capacity for driving drills up to ¼ inch in diameter and is suitable for such work as light drilling, counterboring and the removal of burrs; and the rate of production is said to be very satisfactory. Reference to Fig. 1 will show that the machine is of simple construction. The driving shaft or drill spindle is carried by a ball thrust bearing which enables the spindle to run smoothly at the highest speeds required. The fixture mounted on the slide shown in the accompanying illustration is not part of the regular equipment; but was furnished to meet the requirements of a particular class of work. This slide is operated by a single lever, and the work is carried by a suitable fixture secured to the top face of the slide. An adjustable stop governs the depth to which the hole is drilled. The opposed-spindle drilling machine shown in Fig. 2 is constructed along the same lines as the single-spindle machine shown in Fig. 1. The capacity of this machine is also for drills up to ¼ inch in diameter.

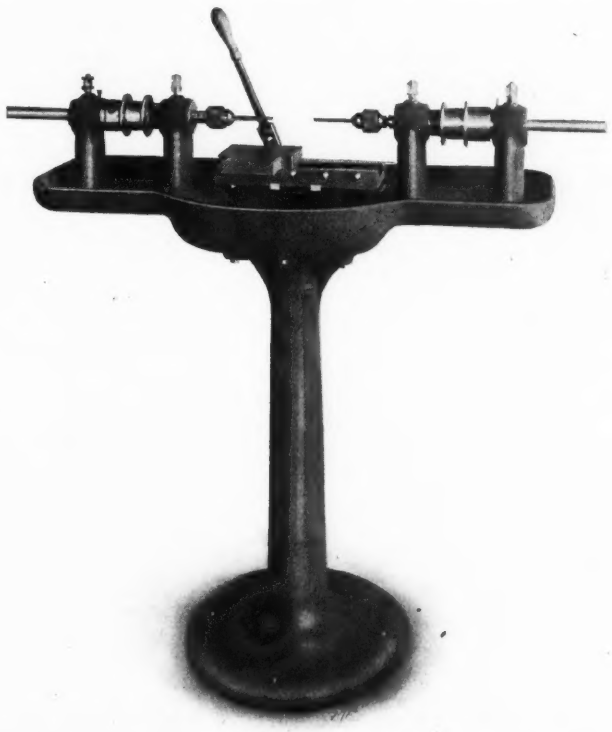


Fig. 2. National-Acme Style D Double-spindle Drilling Machine

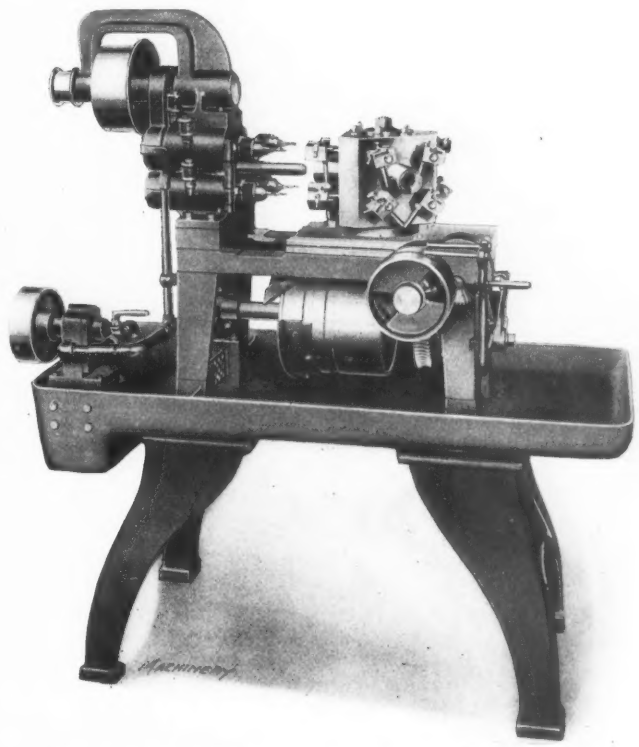


Fig. 3. National-Acme No. 4 Four-spindle Drilling Machine

The multiple-spindle drilling machine shown in Fig. 3 is semi-automatic in operation. It is known as the No. 4 multiple-spindle drilling machine and is equipped with four drilling spindles and a three-sided turret on which the work is carried. The capacity is for driving drills up to 3/16 inch in diameter when working in steel, and for drills up to 5/16 inch in diameter when working in brass. The machine is particularly adapted for the drilling of pins or holes in screws and similar parts, in addition to performing general drilling operations. In operation, it is customary to employ fixtures which provide for holding four pieces of work on each face of the turret, and in order to increase the rigidity of the turret as the work is fed forward to the drills, the turret is engaged by a pilot which enters the bushing in its face, thus maintaining precise alignment. As the turret

RATE OF PRODUCTION AND CHANGE-GEARS FOR NATIONAL-ACME NO. 4 FOUR-SPINDLE DRILLING MACHINE

Pieces Per Ten Hours	Gears on Worm Shaft		Gears on Stud		R.P. 10 hours of Cam-shaft
10035	50	41	26	35	2508
9265	53	41	32	44	2316
8720	53	41	26	38	2180
8440	50	35	41	56	2110
7850	50	35	32	47	1962
7600	50	35	29	44	1900
7310	50	35	26	41	1828
6965	50	32	35	53	1741
6710	53	35	29	47	1678
6230	50	32	26	44	1557
5770	50	29	32	53	1442
5285	50	29	26	47	1321
4685	50	26	29	53	1171
4185	53	26	29	56	1046
3945	56	26	32	62	996
3760	56	26	29	59	939
3575	59	26	32	65	893
3395	59	26	29	62	848
3080	62	26	29	65	770
2810	65	26	29	68	702
2570	68	26	29	71	642
2210	71	26	26	71	552
1880	71	24	24	71	470

Machinery

slide is drawn back, the turret is automatically indexed through one-third revolution, after which it is once more advanced to drill four more holes in the work. While the drilling is being done on the work clamped to the first face of the turret, the operator removes the finished product on the second face and sets up fresh blanks in the fixture carried by the third face of the turret. It will be evident from this description that the operation of the machine is quite rapid.

Fig. 4. National-Acme Six-spindle Bolt Drilling Machine

The drive is provided by two main belts, one of which drives the drill spindles and provides power for operating the oil pump by means of an auxiliary belt. The second main belt provides power for traversing the triangular work-turret to and from the spindles, the movement being effected by means of cams; and this belt also provides power for indexing and locking the turret for successive drilling operations. Change-gears, which are applied similarly to those on the regular National-Acme multiple-spindle automatic screw machines, are provided for varying the cutting speeds; and the cam-shafts are automatically accelerated during the idle motion by means of an intermittent drive. The approximate productive capacity of this machine and the proper gears to use under different operating conditions are given in the accompanying table. The figures showing production are only approximate, but will serve as a guide when calculating the maximum output which can be expected under various working conditions. The saving of time resulting from the employment of the three-sided work-turret with which this machine is equipped has been found to materially increase the rate of production on certain classes of work as compared with the output obtained from machines where production stops while removing the finished product and setting up fresh blanks. On certain classes of work one man can easily look after two of these National-Acme multiple-spindle drilling machines.

Fig. 4 shows a general view, and Fig. 5 a close view, of the mechanism of a drilling machine which differs considerably from the machines shown in Figs. 1, 2 and 3. This machine is designed for use in drilling transverse holes in six bolts

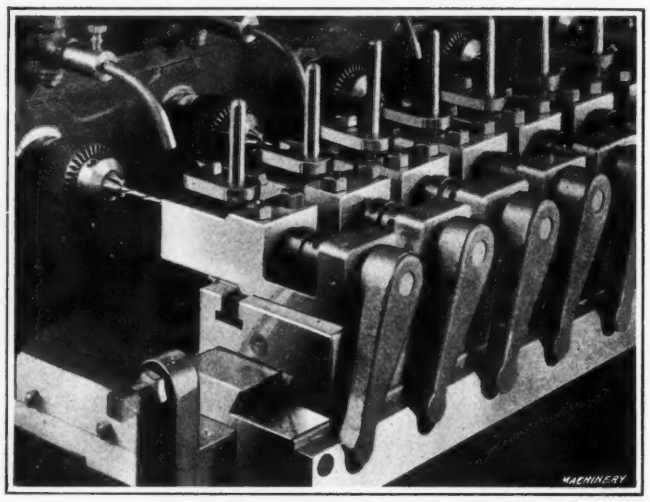


Fig. 5. Close View of Drill Spindles and Fixtures of National-Acme Six-spindle Drilling Machine

at a time. The high rate of production secured by drilling bolts simultaneously is further increased by the fact that provision is made for setting up six blanks in the fixture while the holes are being drilled in six other bolts, the total capacity of the fixture being for twelve bolts, as shown in Figs. 4 and 5. The machine is equipped with a compound slide, the lower slide being for the purpose of moving the work toward or away from the drills, while the upper slide provides the necessary lateral movement for bringing either series of six bolts opposite the drills. Both slides are controlled by levers which are operated by individual cams mounted on a drum and disk, and the same system of change-

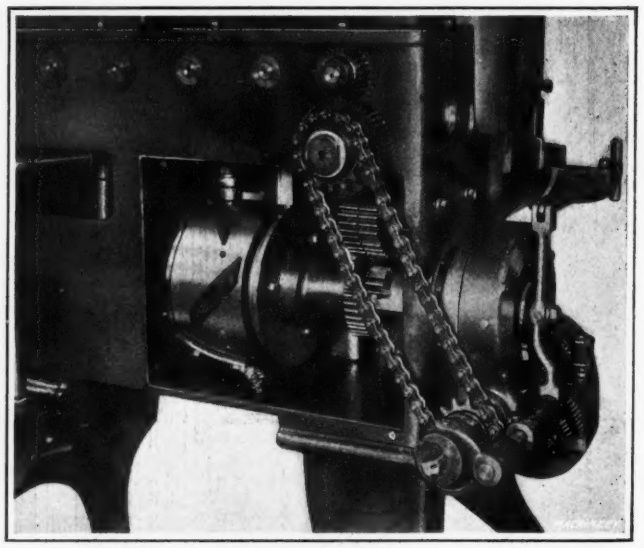


Fig. 6. View of Cam-shaft and Drive to Pump on Machine shown in Fig. 4

gears is employed for varying the speed of the cam-shaft as that which is used on other machines made by the National-Acme Mfg. Co. The change-gears and cams are shown in detail in Fig. 6.

Twelve jigs of suitable design to hold the work to be drilled, are mounted on the top slide; six of these jigs are in line with the drill spindles and hold the work that is to be drilled, while the finished product is being removed from the other six jigs and fresh blanks set up in its place. The jigs in line with the drills are advanced for the drilling operation by means of a compound lever and are returned to the starting point by means of the cam on the disk. As soon as the return motion of the lower slide has been completed, the upper slide is shifted laterally to bring the fresh blanks into line with the drills. The fixtures which hold the finished work are automatically released by the lateral movement of the slide, and the same movement automatically clamps the fresh blanks in the other six fixtures. The machine is particularly adapted for handling small work, and it will be evident from the preceding description that the rate of production will be quite satisfactory. Correct speeds for the drill spindles are secured through a three-step cone pulley which is shown at the right-hand side of the machine in Fig. 4, and a clutch lever gives the operator complete control of the drive. At the top of the machine there is a reservoir for the cutting fluid, and each drill is supplied with lubricant from individual pipes, the supply being adequate for the maximum requirements. The pump, and chain and sprocket which drive it will be seen at the right-hand side of the machine, and in detail in Fig. 6.

IMPROVED WAHLSTROM DRILL CHUCKS

In the May, 1914, and October, 1912, numbers of MACHINERY, descriptions were published of Wahlstrom automatic drill chucks for holding straight and taper shank drills. At the time these articles were published, the Wahlstrom Tool Co., 346 Carroll St., Brooklyn, N. Y., had just taken up the manufacture of drill chucks; and although the service which these tools have been giving during the past three years has been satisfactory, experience has suggested certain improvements in the design. These will be best understood by referring to Figs. 1 and 2, which show the old and improved styles.

In order to explain the improvements which have been made in the design, it will be desirable to describe the operation of the old style chuck for the benefit of those who are not familiar with the construction of this tool. Referring to the end view Fig. 1, the chuck body is shown at *A*, and *B* is a

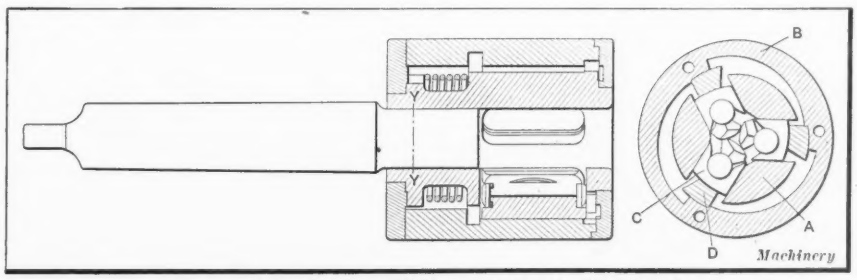


Fig. 1. Early Type of Wahlstrom Automatic Drill Chuck

shell in which three cam surfaces are machined. Between the chuck jaws *C* and the cam surfaces there are extension pieces *D*. The outside of the shell *B* is knurled to provide a good grip for the hand, and by holding this shell back against the rotation of the drill spindle the extension pieces *D* run on their respective cam surfaces, which results in opening the jaws. When the drill is inserted and the shell *B* released, a spring causes the shell to rotate, with the result that the cam surfaces force the jaws into contact with the shank of the drill. The grip secured in this way is sufficient to start the tool cutting, after which the resistance of the cut sets up a torque which causes the eccentric inner jaws to bind against the shank of the drill, the grip obtained being in direct proportion to the amount of power which is required. Fig. 1 shows the chuck jaws in the extreme closed position. When the shell *B* is held back against the rotation of the drill spindle, the extension pieces *D* run on their cam surfaces until engagement is made with the shoulders which separate adjacent cams. At this point the jaws run off the extension pieces into direct contact with the cam surfaces, and the motion is continued until the jaws come up against the side of the next extension piece which abuts against the shoulder at the end of the cam. This is the maximum opening.

The chief objection to the original form of construction lay in the fact that there was a possibility for the extension pieces to be tilted out of alignment with the chuck jaws, due to the introduction of dirt or chips into the chuck. When this condition occurred, the chuck jaws would fail to grip the drill properly and efficient operation of the chuck was

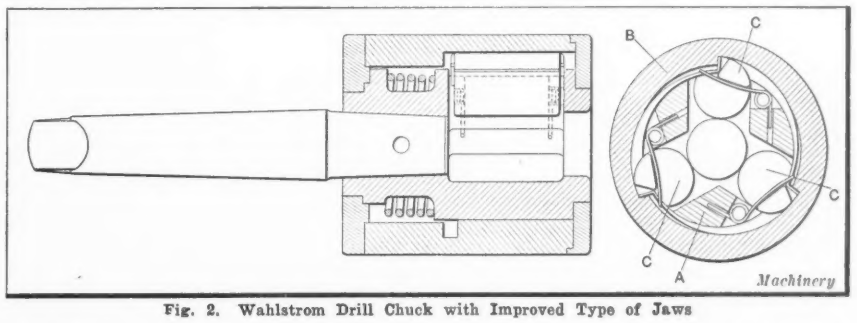


Fig. 2. Wahlstrom Drill Chuck with Improved Type of Jaws

impossible. This difficulty has now been obviated by the employment of an improved form of jaws shown in the end view Fig. 2, which does away with the use of extension pieces, the jaws being in direct contact with the cam surfaces at all times. The method of operation is essentially the same as that described for the old style of chuck, and the end view Fig. 2 shows the chuck in the extreme open position. But in the case of the improved Wahlstrom chuck, each jaw engages only one of the cam surfaces. When the shell of the chuck is held against the rotation of the drill spindle, the jaws run over the cam surfaces until they come into contact with the shoulders at the ends of the cams. After this point is reached, the jaws are rocked over so that the shoulders on the cams enter the spaces provided by the segments which are cut out from the jaws. This is the position shown in Fig. 2. The largest size of drill for which the chuck is adapted can now be slipped up into the chuck, after which the shell is released and the spring causes it to snap back, with the result that the cams force the jaws into contact with the shank of the drill. The jaws are eccentric, and when the drill begins to cut, the resistance causes them to rock around so that their eccentric form makes them bind on the shank of the drill. This principle is the same as that of the original form of Wahlstrom chucks, and as in the earlier type, the grip obtained is in direct proportion to the cutting power required of the drill.

The improved Wahlstrom chucks are made for holding both straight and taper shank drills. The chucks for straight shank drills are made in three different sizes which have capacities for drills from No. 1 to ½ inch, from ⅜ to ¾ inch, and from 17/32 to 1 inch, respectively. The ½-inch chuck has either a No. 1 or 2 Morse taper shank, the ¾-inch chuck either a No. 2, 3 or 4 Morse taper shank, and the 1-inch chuck either a No. 3 or 4 Morse taper shank. Special shanks can be provided to order. The taper shank chucks are made in one size only, and are adapted for holding drills with No. 1, 2 or 3 Morse taper shanks; and the chucks are furnished with either No. 3 or 4 Morse taper shanks. The operation of these chucks is the same as that of the straight shank chucks, and as the jaws grip directly on the shank of the drill, the drive is not in any way dependent upon the tang. No collets are used. As a result, there is no loss of drills from broken tangs where the Wahlstrom chuck is used, and drills which have accumulated in the shop with the tangs twisted off can be made use of.

GLEASON BEVEL GEAR PLANING GENERATOR

The manner in which the generating motion is obtained on this machine represents a departure from the crown gear and segment construction employed on other Gleason bevel gear generators. In the present design, the cradle carrying the tools and the spindle carrying the work are rolled by means of a reversing mechanism, a geared connection being used to transmit the drive to each member. The correct relative roll is secured by means of compound change-gears and a scale is provided to enable the operator to check up the accuracy of the roll at any time. On flat gears of 8 to 1 ratio, the capacity of the machine is for gears up to 32 inches in diameter; and miter gears up to 25 inches in diameter can be handled. The range of pitches is from the finest up to 1½ diametral pitch; and the maximum face width of gears which can be cut is 5 inches.

To meet the requirements of automobile truck builders and other manufacturers who are in need of machines for cutting quiet running bevel gears and pinions, the Gleason Works, Rochester, N. Y., have added to their line a 25-inch bevel gear planing generator of the two-tool type. The capacity of this machine is for flat bevel gears up to 32 inches in diameter for an 8 to 1 ratio; and gears of 45-degree face angle, *i. e.*, the so-called "miter-gears," can be cut in diameters up to 25 inches. The range of pitches for which the machine is adapted is from the finest up to 1½ diametral pitch; and the maximum length of the tool stroke is 6 inches, which provides for cutting gears with a face width of 5 inches.

Provision is made for planing gears with a long hub at the back by allowing enough space so that the end of the work-spindle can be set 20 inches from the tools. To adapt the machine for planing pinions which are an integral part of a long stem, the work-spindle is made hollow so that pinions of this character can be set up with the stem carried inside of the hollow spindle. The time required for finishing one tooth ranges from 30 seconds to 2 minutes 50 seconds, according to the material and the size of the gear which is being cut. The floor space occupied is relatively small in comparison to the size of work which can be handled on the machine, the extreme dimensions being 8 feet 2 inches long by 6 feet 4 inches wide. The net weight of the machine is 11,000 pounds.

The machine works on the generating principle and is fully automatic in operation. The tools are mounted in clapper-blocks which are carried by long slides operating in arms shown at *A* in Fig. 1; and the setting is made for any required length of stroke by adjusting the graduated crank-plate *B*, Fig. 2. The slides are fully protected from chips and dirt, and the arms may be set for any tooth angle by means of a turnbuckle *C*, Fig. 3, and graduations *D*, Fig. 4. After the arms have been set in the required positions, they are securely fastened to the carriage *E*, Fig. 5; the carriage holds the

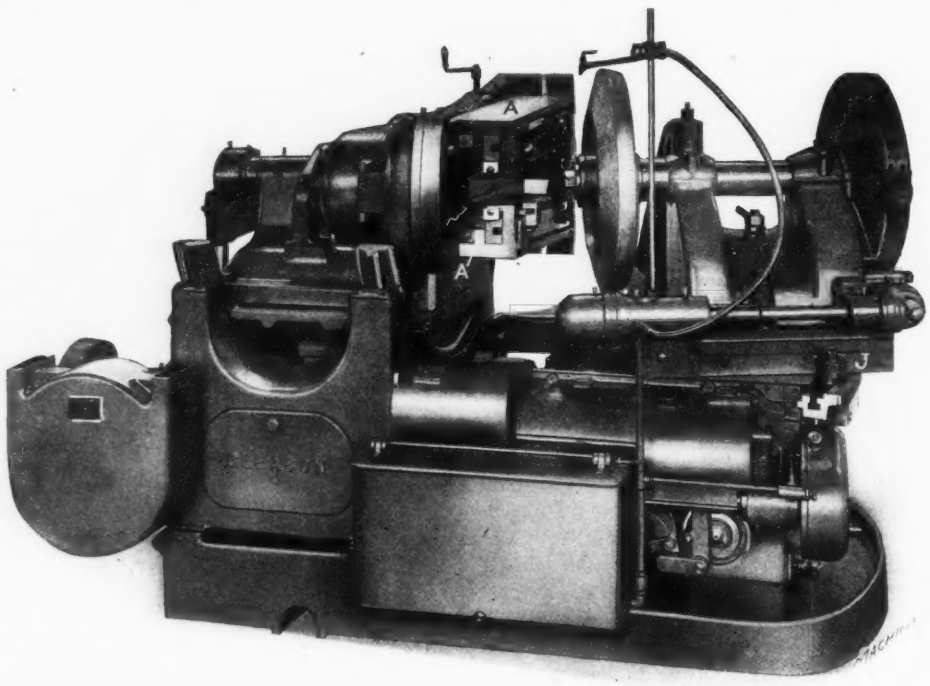


Fig. 1. Gleason 25-inch Bevel Gear Planing Generator

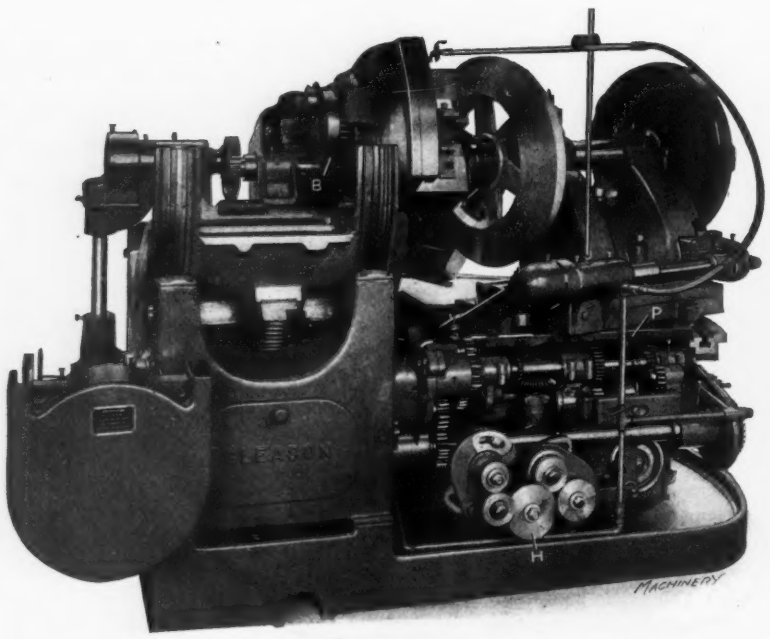


Fig. 2. Covers removed to show Graduated Crank-plate B, Change-gears H and Oil Tubes P

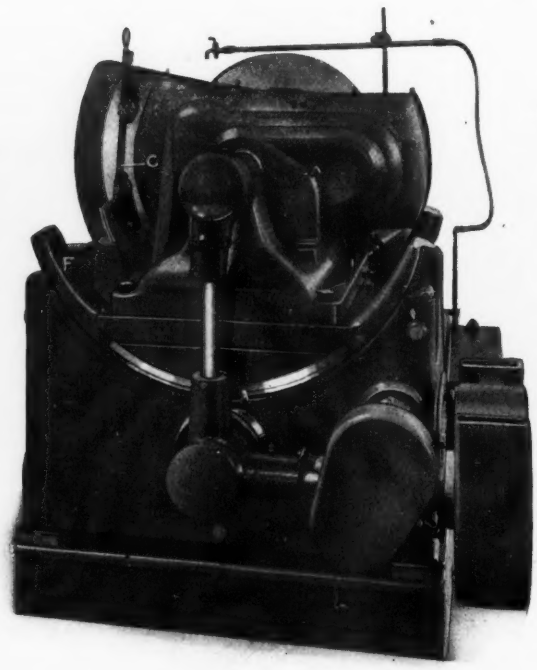


Fig. 3. View of Machine from End on which Tool-cradle is mounted

mechanism for driving the tool-slides and is solidly bolted to a cradle *F*, Fig. 3. The speed of the tool-slide can be varied by means of change-gears *G*, Fig. 5. The cradle *F* has circular V-ways which are designed with liberal bearing surfaces and provided with forced lubrication.

The generating motion employed on this machine represents a departure from the regular Gleason crown gear and segment method. In the present design, the cradle which carries the tools and the spindle which carries the work are rolled by means of a reversing mechanism, and a geared connection is used to transmit the drive to each member. The final pair of gears in each train is a worm and worm-wheel which are made of suitable pitch to insure accurate control. The correct relative rolling motion of the cradle and work-spindle is secured by means of compound change-gears, shown at *H* in Fig. 2; and the graduations *I*, Fig. 4, allow the operator to check up the accuracy of the rolling motion. The indexing mechanism is positively driven and operates by one turn of a stop-plate. This motion is joined with the drive for the generating roll of the work by means of a differential mechanism, and a single train of driving members carries the combined motions to a worm-wheel on the spindle. This arrangement permits of employing a very compact design which does away with the swinging bracket construction used on earlier types of Gleason bevel gear generating machines, thereby saving a considerable amount of floor space.

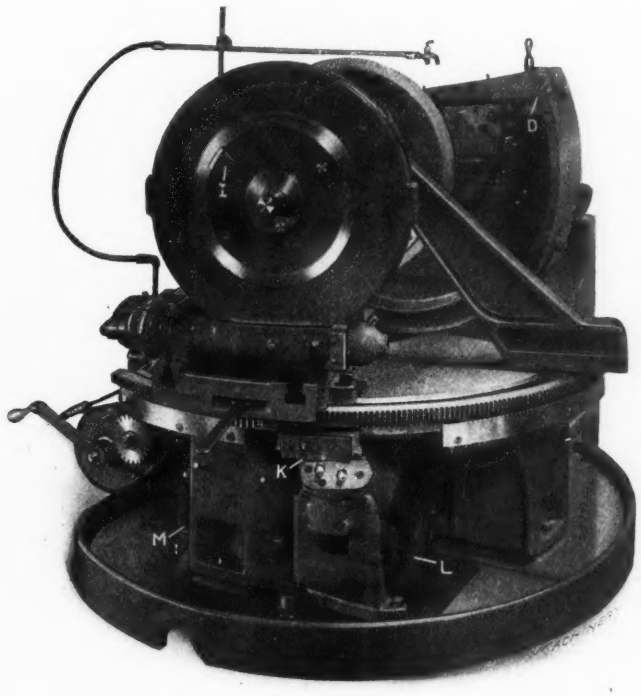


Fig. 4. View of Machine seen from Work-spindle End

The head is carried on a swinging base *J*, Fig. 1, which carries the work to the tools; and the proper depth of cut is obtained by adjusting the graduated lever *K*, Fig. 4. The base *J* is driven by cam *L* and the cam, in turn, receives its motion from a worm and worm-wheel which run in an oil bath *M*. The tools are of the rack tooth type, and can be made to 14½-, 20-degree or any other pressure angle which may be required. The cutter is made of high-speed steel and mounted on a carbon steel holder, as shown in Fig. 6, where it will be seen that the cutter is positively located on the holder by means of a double tongue and groove joint. Owing to the present cost of high-speed steel, this type of tool is far more economical than a solid tool, and aside from the saving in cost the arrangement has the further advantage of enabling the cutters to be quickly interchanged when they require regrinding or when gears of some other pitch are to be cut.

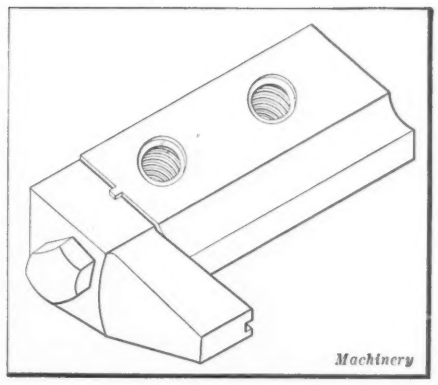


Fig. 6. Form of Tool-holder used

The oiling of all worm-wheels, cradle-ways, heavy-duty gears and cutting tools is effected by a system of forced lubrication which receives oil from two pumps that are located inside of the cradle base at *O*, Fig. 5, where they are accessible at all times. Aside from the saving of space which is secured by this arrangement, there is the further advantage of having all gears and driving chains fully guarded. All other oil tubes on the machine are grouped in convenient places as shown at *P* in Fig. 2, so that the operator is not likely to overlook any of them. All gears on the machine, with the exception of the change-gears, are made of steel and casehardened to make them durable. The tools are easily and accurately set by means of gages which may be tested at any time with a proof plug; and the gear blank to be cut can also be quickly set up on the work-spindle by means of a cone distance gage. These provisions which are made for the rapid adjustment of the machine in connection with the features of the design which afford rapid and automatic operation, make the rate of production very satisfactory.

ROCKFORD 17-INCH ENGINE LATHE

In the October, 1914, number of MACHINERY a description was published of the 13-inch "Economy" engine lathe manufactured by the Rockford Lathe & Drill Co., Rockford, Ill. Since the appearance of the article referred to, this concern has added to its line a 17-inch engine lathe, the design of which is essentially the same as that of the smaller sized machine. It is built in two types, one of which is equipped with a quick change-gear mechanism and the other with what is styled as a "semi-quick" change-gear device. In the former type of machine the feed-box is of simple and powerful construction; all gears are cut from solid steel and thirty-two changes are obtained through sliding gears and hardened steel clutches that are

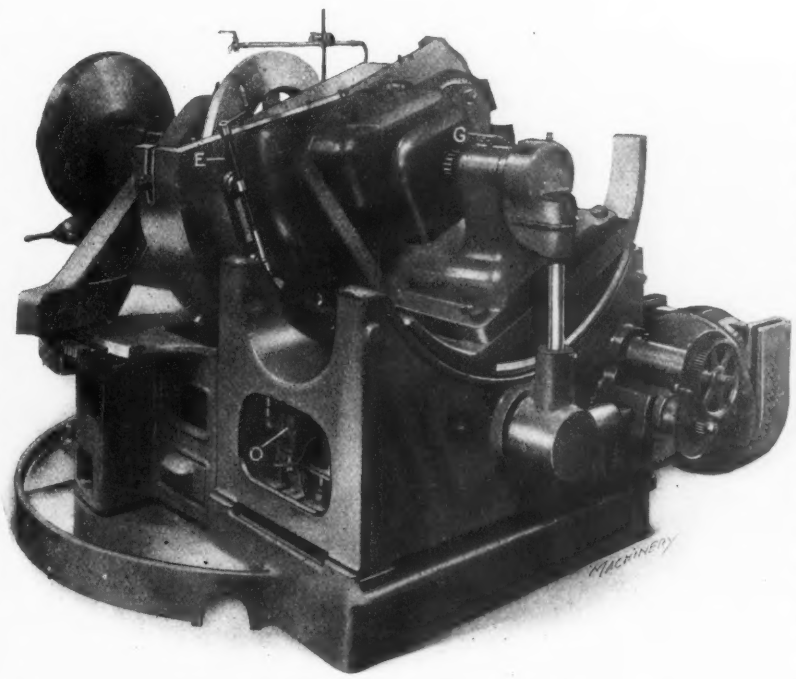


Fig. 5. Opposite Side of Machine from that shown in Figs. 1 and 2

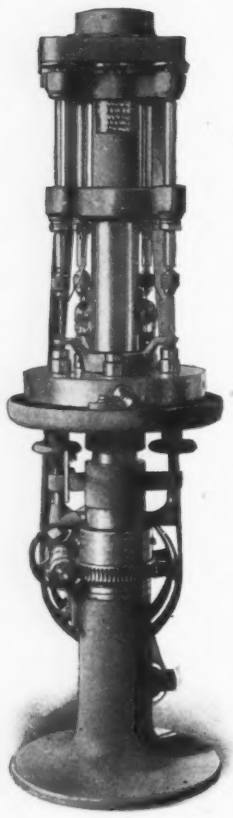


Fig. 1. Front View of Bemis Four-spindle Semi-automatic Drill

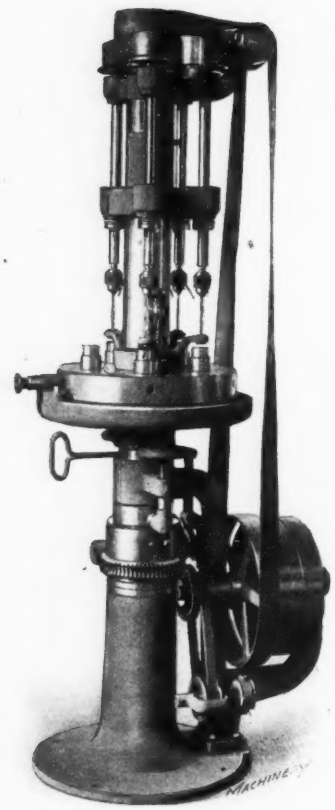


Fig. 2. Side View of Bemis Drill

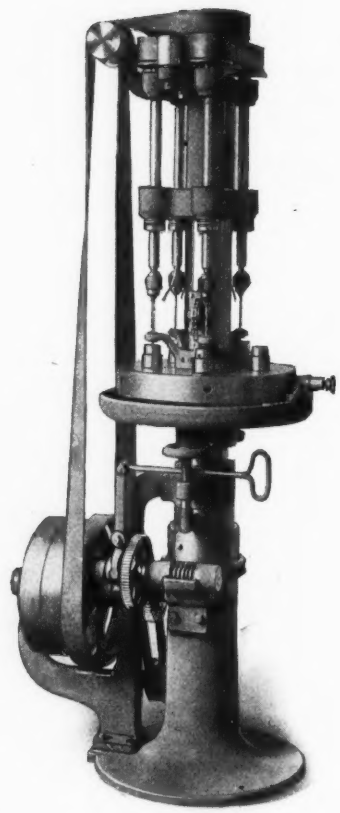


Fig. 3. Opposite View of Machine shown in Fig. 2

controlled by two handles. The lead-screw and feed-shaft operate independently, and either the screw or shaft is engaged by operating a knob at the front of the gear-box. In the lathe with the semi-quick change-gear box, three changes of feed are obtainable for each change of gearing through sliding steel gears and hardened steel clutches which afford a powerful drive. This gear-box simplifies thread cutting operations, as all pitches are obtainable without the necessity of compounding gears. These new lathes swing 18½ inches over the ways and 11¾ inches over the carriage; the distance between centers on a lathe with a 6-foot bed is 27 inches. The ratios of the double back-gears are 3.5 to 1 and 11.13 to 1, respectively. The machine is built with 6-, 8-, and 10-foot beds.

BEMIS FOUR-SPINDLE DRILL

The semi-automatic four-spindle ball bearing drill shown in the illustrations presented in connection with the following description, was developed by Edgar W. Bemis, Worcester, Mass., for use in drilling clearance holes in threading dies and for similar work. The table is equipped with five chucks so that the finished work may be removed from one chuck and a fresh blank placed in position while the drills are working on the pieces held in the other four chucks. The general arrangement of the machine will be readily understood by reference to the front, rear and side views shown in Figs. 1, 2 and 3; and from Figs. 4 and 5, which show the index mechanism and method of driving. In operation, the piece to be drilled is set up in the chuck at the front of the machine, the lock-pin is withdrawn and the table revolved to bring the work under the first spindle. While the table is being raised to feed the work to the drill, the operator places another piece in the second chuck and continues setting up work until all of the chucks have been filled. After the operation has once been started in this way, it is merely necessary for the operator to remove the finished piece and set up a fresh blank in each successive chuck as it comes to the idle position at the front of the machine.

The work-table is supported on ball bearings on the lifting table which is moved up and down to feed the work to the drills and withdraw it after the operation has been completed. The work-spindles have gears keyed to them which mesh with a gear carried by the hub of the lifting table. As the work-table is indexed to bring the work-spindles into successive positions under the four drill spindles, the gears just referred to index the work to the proper positions for drilling. The feeding of the work-table to and from the drills is effected by means of rolls carried on the lifting rods; these rolls run on cams fastened to a worm-gear which re-

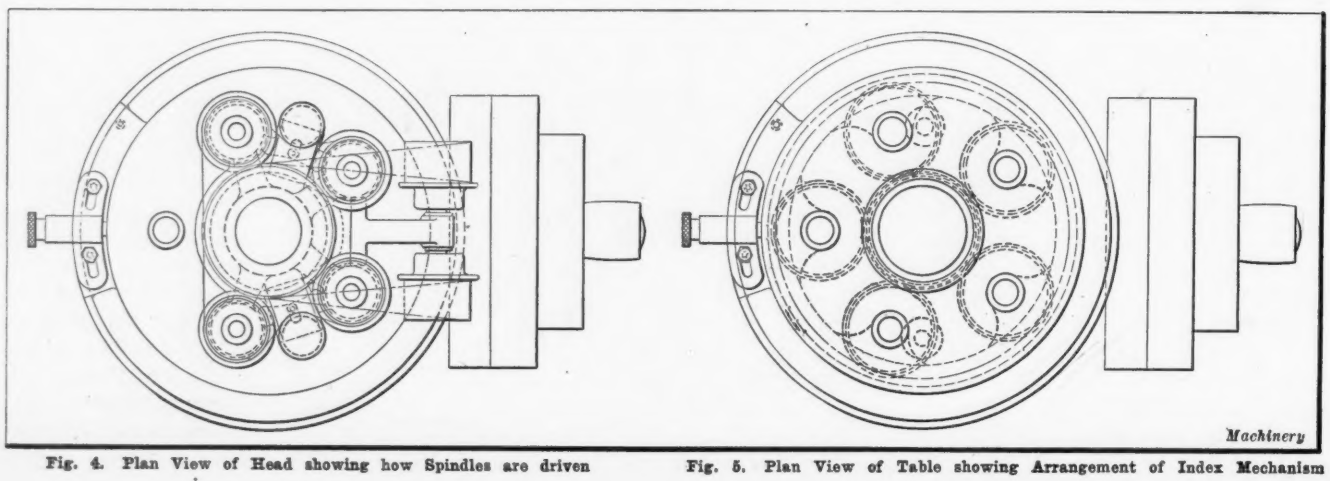


Fig. 4. Plan View of Head showing how Spindles are driven

Fig. 5. Plan View of Table showing Arrangement of Index Mechanism

volves around the post and is driven by the gears on the main driving shaft. A stud at the top of the post supports a cone pulley, the top step of which receives the belt which runs over idler pulleys from the main driving pulley. An endless belt runs around the four pulleys on the drill spindles, and the desired tension of this belt is maintained by means of idler pulleys.

The locking-pin which locks the work-table to the lifting table is adjustable to allow the center of the chucks on the work-table to be moved from the centers of the drills, thus enabling four holes to be drilled on any circle up to 3½ inches in diameter. A convenient handle located at the side of the machine operates a sliding clutch on the worm-shaft to provide for stopping or starting the feed. The worm-gear which carries the lifting cams rests on ½-inch falls, thus reducing the frictional resistance. The lifting cams fastened to the worm-gear may be adjusted to provide for drilling to any required depth which comes within the range of the machine. The lifting rods on each side of the machine are threaded for a part of their length, and the rods pass through handwheels that are used to adjust the position of the table relative to the drills. The shank of the chuck is drilled half way through its length so that long drills can be put up in the shank and then drawn down to any required position. An oil chamber is cored around the head of the drill behind the spindle bearings, and valves are tapped into this chamber to make connection with pipes which carry oil to each of the drills. A pump driven from the main shaft keeps the chamber full of oil. The capacity of this machine is for drilling holes through 1800 pieces of 5/16-inch stock per day.

Royersford Improved 20-inch Double Back-geared Drill

WHITNEY HAND-OPERATED PUNCHES

The accompanying illustrations show three hand-operated punches which constitute recent additions to the line of punches and shears made by the Whitney Metal Tool Co., Rockford, Ill. In addition to punching metal, these tools may also be employed for setting the heads of rivets, in which service they give very satisfactory results.

Fig. 1 shows the No. 15 ball bearing punch which has a capacity for punching holes up to 5/16 inch in diameter through iron 5/16 inch in thickness. The tool will reach to the center of a 7¾-inch disk, and the height of the gap is ⅜ inch. One-half turn serves to drive the punch through ¼ inch of metal. The weight of the tool complete is 21 pounds. The No. 20 ball bearing punch shown in Fig. 2 is made of chrome-nickel steel, heat-treated to obtain the required properties. The capacity of this tool is for punching holes up to ½ inch in diameter through iron ½ inch in thickness. The depth of the throat is 2 inches, the height of the throat 1⅜ inch, and the weight of the tool 20 pounds.

Fig. 3 shows a No. 40 ball bearing punch which, like the No. 15 punch shown in Fig. 1, is equipped with a ratchet head and socket handle. The capacity of this tool is for punching holes up to ¾ inch in diameter in iron ¾ inch in thickness; the depth of the throat is 3 inches, the height of the throat 2 inches, and the weight of the tool 51 pounds. The No. 15 tool requires a pressure of 15,300 pounds to punch a hole 5/16 inch in diameter through iron 5/16 inch in thickness. The No. 20 tool requires 39,300 pounds pressure to punch a hole ½ inch in diameter through iron ½ inch in thickness. The No. 40 tool requires a pressure of 88,400 pounds to punch a hole ¾ inch in diameter through iron ¾ inch in thickness.

ROYERSFORD DOUBLE BACK-GEARED DRILL

The design of the improved 20-inch double back-geared drill which has recently been placed on the market by the Royersford Foundry & Machine Co., Royersford, Pennsylvania, combines the features of simplicity, strength and rigidity with speed and accuracy of production. The capacity is for drilling holes up to 1½ inch in diameter. All the gears are machine cut, and the bearings are liberally proportioned; the change from direct to double back-geared drive or *vice versa* is instantly obtained by simply sliding the gears in to or out of mesh. It will be seen from the illustration that the drill is made with a square base.

Eight changes of speed are provided, and the feed may be obtained by power, by hand through a feed wheel, or by means of a feed lever. The spindle is counterbalanced by a

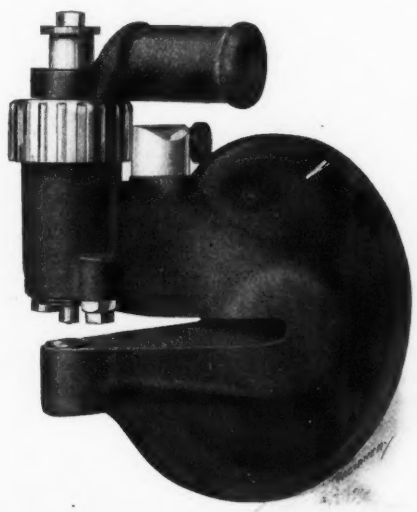


Fig. 1. Whitney No. 15 Ball Bearing Punch for Sheet Iron up to 5/16 Inch in Thickness

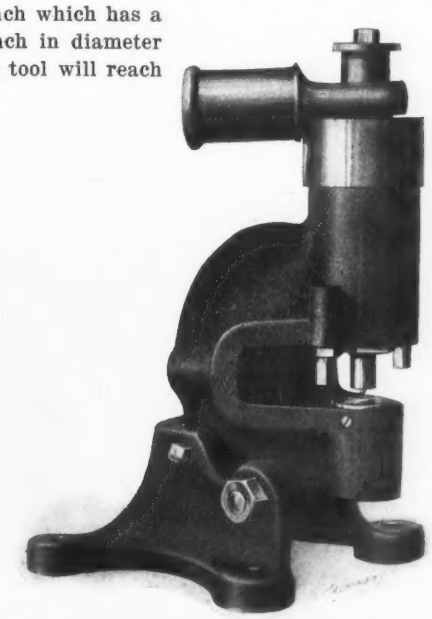


Fig. 2. Whitney No. 20 Ball Bearing Punch for Sheet Iron up to ½ Inch in Thickness

Fig. 3. Whitney No. 40 Ball Bearing Punch for Sheet Iron up to ¾ Inch in Thickness

weight inside the column and is provided with an automatic stop and quick return. There is a quick-acting screw for raising or lowering the table. The principal dimensions of the machine are as follows: maximum distance between table and spindle, 36 inches; maximum distance between base and spindle, 45 inches; distance from column to center of spindle, 10¼ inches; diameter of column, 5¼ inches; traverse of spindle, 9 inches; traverse of table on column, 21½ inches; diameter of table, 18 inches; floor space occupied, 23 by 50 inches; horsepower required to drive drill, 1; and net weight of machine, 800 pounds.

"MODERN" COLLAPSIBLE TAP

The collapsible adjustable tap illustrated and described herewith is a recent product of the Modern Tool Co., Erie, Pa. This tool is designed for use in machining shrapnel and high-explosive shells, and it is said that it is constructed along such rigid lines that it possesses practically the same strength as a solid tap. The design of the mechanism is extremely simple, yet it governs the operation of the tool in such a way that the collapse of the tap is insured at any predetermined point, thus permitting the quick withdrawal of the tool without injury to the work. In addition to the collapsing feature, the construction provides for making adjustments for producing tight and loose threads.

The cutting members consist of but two parts, being identical with a solid tap split through the center. Each blade has two or more flutes—as in the case of a solid tap—and the shank of the blades terminates in a square base which is inserted in a correspondingly shaped hole in one of the two slides in which the blades are fastened by set-screws. These two slides are secured in a T-shaped groove in the head, and are movable transversely to enable the blades to slide past each other. In this way the diameter of the cutting tools is reduced or increased as required. Each sliding block terminates on the outer end in a curved surface which is operated upon by cam surfaces on the inside of a ring which encircles the blocks. These cams are of sufficient depth to force the sliding blocks to move in opposite directions through a distance sufficient to bring about the collapse of the tap, so that it is clear of the work and may be rapidly withdrawn when the tapping is completed.

The head which carries the sliding blocks and cam ring is mounted on a shank that is clamped in the chuck or turret head in the usual manner. The shank may be made integral with the head or provided with longitudinal float as desired. It will be evident from the description and illustrations that, in designing this tap, the Modern Tool Co. has utilized the same principles and practically the same construction as employed in the Modern self-opening and adjustable die-head.

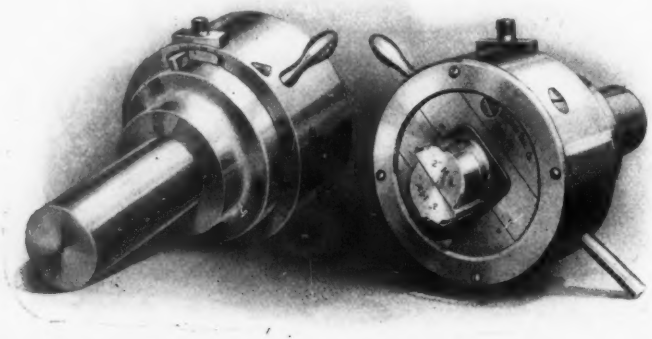


Fig. 1. Collapsible Tap made by the Modern Tool Co.

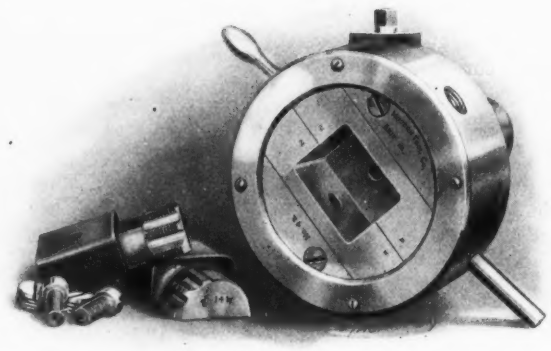


Fig. 2. Parts of Modern Tool Co.'s New Tap

The chief points of difference are that the slides have been reduced to two in the case of the tap, and that the cutters are made for cutting internal threads instead of external threads. As the operation of the tool is controlled by cams and springs which are independent of the cutting members, and as there are no delicate parts inside the tap, work of exceptionally small diameters may be threaded. This tap is made in four sizes ranging from ½ to 3 inches in diameter.

HECO ELECTRIC TEMPERING OVEN

The enviable reputation which is enjoyed by English toolsmiths was built up in the days when the equipment available for hardening tool steel consisted of a coke fire. After the tools had been hardened, the method of tempering consisted of heating a large block of steel to a cherry red, and then placing the hardened tools on this block until their temperature had been raised to the desired degree as indicated by the color, which ranged from straw to a dark blue. Although the results obtained by this method were of such a high quality that the reputation established by the old English toolsmiths has been held to the present day, the method of tempering referred to is not adapted to the requirements of modern manufacturing. To provide for handling work more rapidly, the general method of tempering in American manufacturing plants consists of immersing the hardened parts in a bath of oil, the temperature of which has been raised to the proper degree. There are, however, certain undesirable features connected with this process, such as the difficulty of handling the work, the untidy appearance of the tempering room, which is unavoidable, and the fact that the best grades of tempering oil cannot be heated above 600 degrees F., so that the method is not adaptable for tempering many classes of high-speed steel which require the application of higher temperatures.

Heco Electric Tempering Oven for which H. B. Eaton & Co. have the Selling Agency

With the view of developing a method of tempering which would obviate the objectionable features of the oil tempering bath, and enable work of the high quality produced by the old English toolsmiths with their heated steel blocks to be turned out at a rate that could meet modern conditions of competition, the Heco Mfg. Co., Boston, Mass., has developed the electric tempering oven shown in the accompanying illustration, for which H. B. Eaton & Co., Inc., 144 Pearl St., Boston, Mass., have the eastern sales agency. The advantages of the method of "dry" tempering may be briefly outlined as follows: The metal can be brought to a uniform condition from the outer surface to the center of the work; and with the Heco electric oven, the work can be handled even more rapidly than in the case of the oil bath. Any desired temperature is available up to 800 degrees F., the control being maintained by a rheostat. The heating units are placed at

the bottom of the oven and are located in parallel rows from front to back, so that every part of the oven receives an absolutely uniform heat, with the result that the temper of all parts is drawn uniformly. The ovens are provided with 4-inch heat retaining walls, and it is stated that with a maximum temperature of 800 degrees F. the exterior remains cool.

With intelligent use, the ovens should last for years, but the heating units require renewing after approximately 3000 hours of service. The Heco electric tempering ovens are made in three stock sizes, known as Nos. 1, 2 and 3. The No. 1 oven is 12 inches wide by 12 inches deep by 8 inches high, and the approximate consumption of electric power is 1000 watts per hour. The No. 2 oven is 18 inches wide by 18 inches deep by 8 inches high and the approximate consumption of electric power is 1500 watts per hour. The No. 3 is 24 inches wide by 24 inches deep by 8 inches high and the approximate consumption of electric power is 2000 watts per hour. All sizes of ovens are made for various voltages and for use on alternating or direct current.

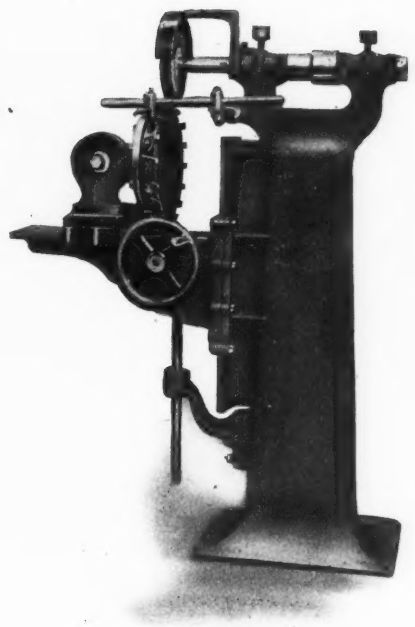


Fig. 1. Grinding an Inserted-tooth Milling Cutter

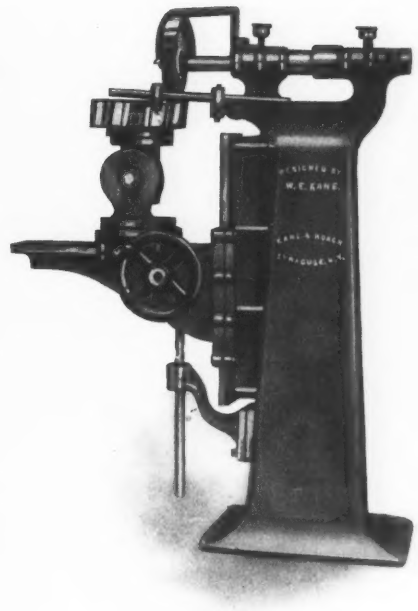


Fig. 2. Cutter held on Mandrel in Vertical Position

KANE & ROACH GRINDER

The grinding machine which forms the subject of this article is a recent product of Kane & Roach, Niagara and Shonnard Sts., Syracuse, N. Y., and is adapted for grinding all kinds of milling cutters. The illustrations show the machine set up for four typical operations, which will give the reader an idea of its range. This machine has been in use in the manufacturers' shops for a considerable time, during which it has been employed on a great variety of cutter grinding work, and the experience gained has enabled weak features to be eliminated. All the attachments used on the machine are graduated in degrees so that they can be swiveled or tilted to any angle that may be required by the work. Also, the head can be moved in or out, and the table can be raised or lowered into any desired position. The result is that the grinding machine is adapted for a wide range of work.

The countershaft is furnished with the machine and the cone pulley provides two changes of speed. The different grinding wheels used on the machine are carried by taper shank mandrels. The swinging or swivel sleeves which carry the work are made to fit bushings for the various forms of straight or tapered shanks on the cutters or mandrels. These bushings and mandrels are not furnished with the machine, as it is necessary for the user to make the attachments to suit his own particular work. The swivel head, which is ready to receive the work-holding bushings, constitutes part of the regular equipment of the machine, and the same is true of the countershaft. The floor space occupied is approximately 3½ feet by 1 foot 8 inches, and the complete height is 3½ feet.

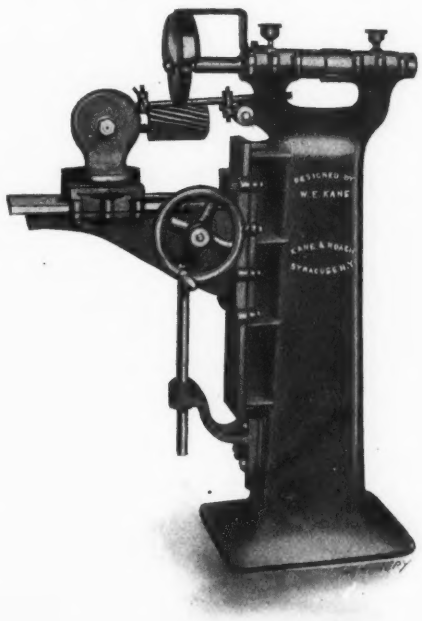


Fig. 3. Cutter held on Mandrel in Horizontal Position

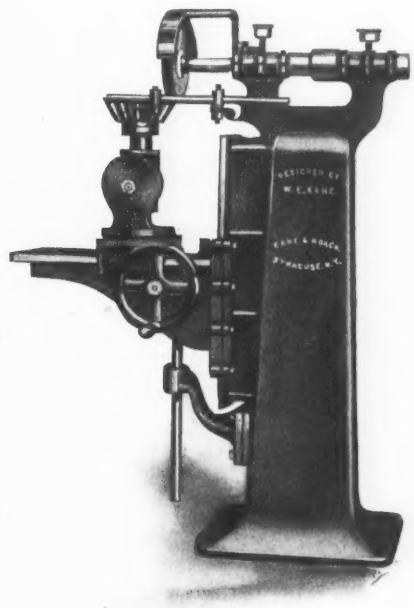


Fig. 4. Grinding a Tapered Milling Cutter

ANDERSON DIE FORMING MACHINE

The machine shown by the illustrations presented in connection with the following description is built by the Anderson Die Machine Co., 590 Water St., Bridgeport, Conn., and is especially adapted for finishing blanking dies and similar work after the hole has been roughed out in the usual way. It is driven by a motor that can be attached to an ordinary lamp socket. It will be evident from the illustrations that the machine is equipped with a special cutter which is shaped like a file but operates more on the principle of a milling cutter. The cutting edge is one continuous spiral, and the cutter is driven by a rotating spindle. The die is fed up to the cutter by hand. The following advantages are claimed for the machine: First, that it cuts very rapidly and without interruption; second, that it is unnecessary to change the cutter for every variation in contour of the surface being operated upon; third, that the work-table is always set at right angles to the spindle so that the cutter, which has the same taper as the clearance required in the die, always produces a uniform clearance regardless of how the work is presented to the cutter. The result is that when the die is ground to renew its cutting edge, the opening is uniformly enlarged without distortion.

The motor is connected to the horizontal driving shaft on the machine by means of a semi-flexible

Fig. 1. Control Side of Anderson Die Forming Machine

coupling, and connection between the driving shaft and vertical spindle is by means of a pair of spiral gears. It will be seen that the driving mechanism is completely enclosed with the exception of a small opening at the bottom of the case, which provides ventilation to prevent heating of the electrical parts. The design of the motor windings has been worked out with particular reference to the intermittent loads to which the Anderson die forming machine is subjected.

The cutter is carried in the machine by means of a hardened and ground collet which is held in the closed position by a powerful spring at the lower end of the spindle. When it is desired to remove the cutter from the spindle, the collet is opened by raising the hand lever. The spindle is hardened and ground, and runs in phosphor-bronze bearings; the upper bearing is of the double angle type and the lower bearing of the straight type. An adjustable thrust collar is provided to engage the lower face of the upper bearing, thus reducing to a minimum the changes in adjustment resulting from variations of temperature. A knurled ring is provided on the end of the spindle which prevents chips or dust from finding their way into the bearings. The centrifugal force due to the rapid rotation of the spindle largely prevents the lodging of chips or dust in the collet, but should the collet require cleaning, the table can be tilted back to make it easily accessible, this position being shown in Fig. 2. A switch is located on the base of the machine for starting or stopping the motor.

The cutters used on this machine are so designed that the use of feed-screws, slides or vises is unnecessary for holding the work and feeding it up to the cutter. The work is held by hand and guided up to the cutter in any direction, so that either straight or irregular lines can be followed. The cutting is the result of a continuous shearing action of the tool, which not only removes the excess stock from the die but also serves to hold the die-block down on the table. As all chips are carried down, no trouble is experienced from the obscuring of the outline laid out on the die-block. The cutting edge of the tool is not subjected to any appreciable shock while in operation, and so it will be evident that the life of the tools is quite satisfactory. Cutters for die work can be furnished to produce any desired degree of clearance, and they can be made to leave the die straight for ⅛ or 3/16 inch, after which the clearance is of the usual form. All sizes of cutters are made with shanks ¼ inch in diameter so that it is unnecessary to change the collet in the machine when a change of cutters is necessary.

The cutting action of the tool is such that wooden patterns can be formed to give the required draft and there is no danger of splitting the wood, no matter what direction the grain runs in. The finish produced is very smooth and the pattern will require very little, if any, hand work to be done on it after leaving the machine. The draft on the pattern will be uniform on all sides because the amount of draft is controlled by the taper of the cutter. Suitable cutters are made to produce any required degree of draft for wooden or metal patterns. The regular equipment furnished with the machine includes the driving motor, a heavy flexible cord and attachment plug, a fixed or portable tool rack, and a set of twelve cutters of any form that may be desired. In addition to its application for finishing blanking dies, the machine will be found useful in making irregular-shaped drawing dies, templets, small sheet metal model parts, formers for profiling gages, irregular-shaped gages, formers for cams, metal patterns, and small wooden patterns. The principal dimensions of the machine are as follows: Capacity, for finishing dies up to 1½ inch in thickness; size of cutters used, ⅛ to 5/16 inch in diameter; size of table, 7 inches in diameter; height of table from bench, 10¼ inches; bench space occupied, 9 by 18 inches; and weight, including motor, 551 pounds.

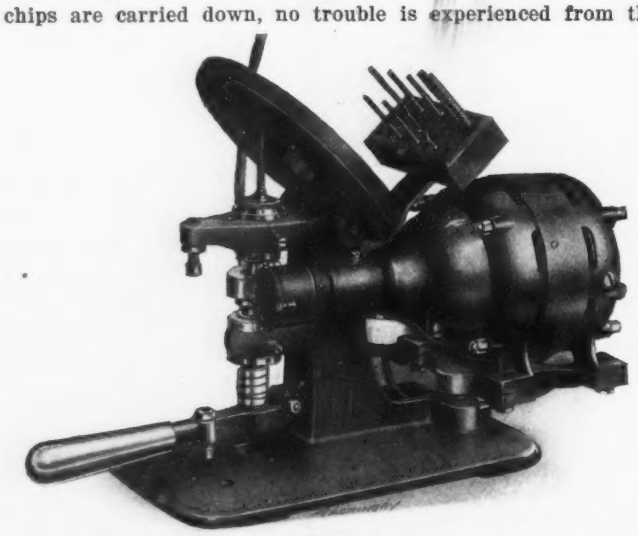


Fig. 2. Opposite Side of Machine showing how Motor and Gearing is covered

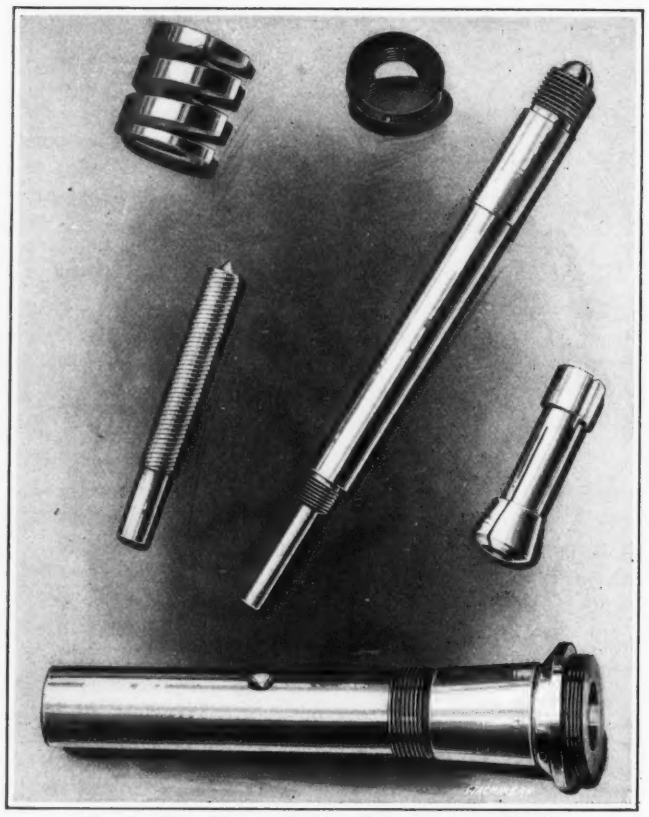
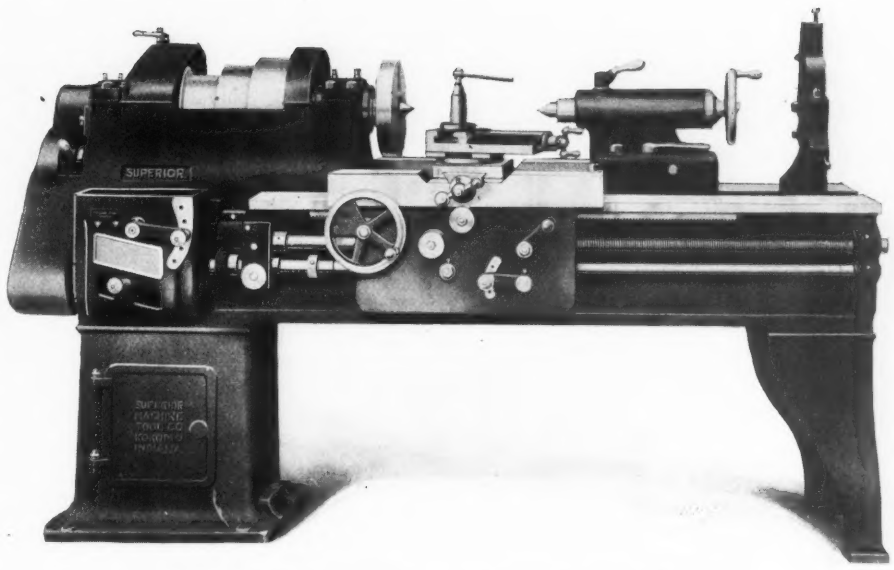


Fig. 3. Close View of Cutting Tool, Collet and Spindle

"SUPERIOR" ENGINE LATHE

The unusual demand which now exists for many types of machine tools makes the question of prompt delivery of great importance to many prospective purchasers. This is particularly true of lathes which are being used in great quantities both in this country and Europe for the turning of shrapnel and high-explosive shells. The Superior Machine Tool Co., Kokomo, Ind., has recently added to its line an 18-inch engine lathe which is shown in the accompanying illustration, and

this concern announces that it is in a position to make early deliveries on orders. It will be seen that the design of the machine follows closely established practice in the construction of modern engine lathes, and the features of the machine will be evident from the illustration without requiring a detailed description.



Engine Lathe manufactured by the Superior Machine Tool Co.

The principal dimensions of the machine are as follows: Swing over bed, 18½ inches; swing over carriage, 11½ inches; size of front spindle bearing, 3⅛ by 5 5/16 inches; size of rear spindle bearing, 2 7/16 by 4½ inches; diameter of hole through spindle, 1 9/16 inch; diameter of spindle nose, 2 11/16 inches; width of belt for machine with four-step cone pulley, 3½ inches; width of belt for machine with three-step cone pulley, 3¾ inches; size of cutting tool, ⅝ by 1¼ inch; diameter of tailstock spindle, 2¼ inches; length of carriage bearing on bed, 27 inches; ratio of back-gears, 3.27 to 1 and 10.5 to 1; size of countershaft pulleys, 12 by 4 inches; speed of countershaft, 225 to 400 R. P. M.; lengths of beds furnished on machine, 6 to 16 feet; distance between centers for machine with 8-foot bed, 56 inches; net weight of machine with 8-foot bed, 3600 pounds; and additional weight per foot of bed, 145 pounds.

NEWTON WORM-WHEEL HOBBING MACHINE

In a worm-wheel hobbing machine which has recently been added to the line of the Newton Machine Tool Works, Inc., Philadelphia, Pa., provision is made for generating the teeth with either a tapered hob or fly-cutter. The generating tool has the general form of a tap and is set in the same position as that occupied by the worm when in mesh with the wheel, *i. e.*, at the same distance from the axis and at the same angle with the plane of the wheel. The general practice in hobbing is to cut the wheel teeth to a gradually increasing depth by feeding the cutter in a radial direction toward the center of the wheel. On the Newton hobbing machine this practice is not followed; in the present case the cutter is fed along a tangent to the wheel. As a result, the smallest diameter of the

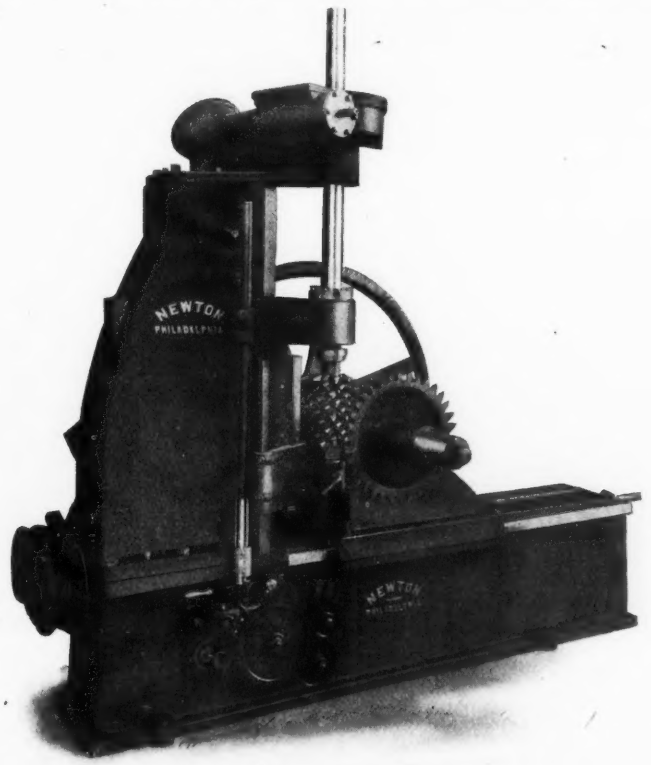


Fig. 1. Newton Worm-wheel Hobbing Machine equipped with One of the Special Tapered Hobs

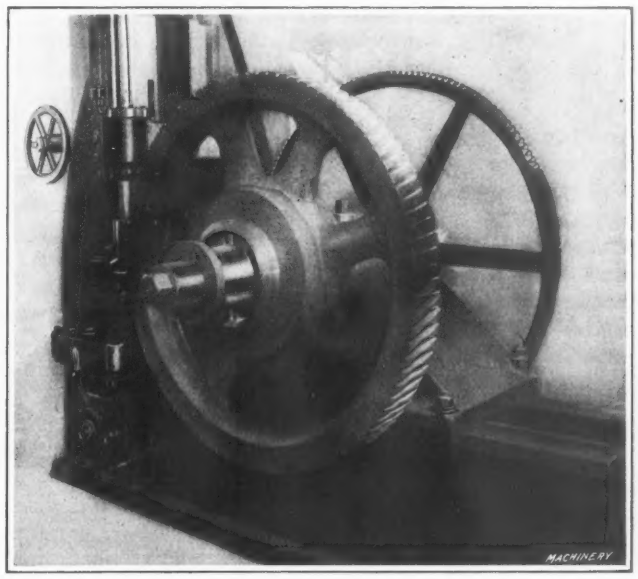


Fig. 2. Generating Worm-wheel with Fly-cutter

tapered hob starts cutting, and as the hob is fed across the wheel, the taper causes the teeth to cut to steadily increasing depths. The largest diameter of the hob cuts the teeth to the required depth. Fig. 1 shows the machine generating a worm-wheel with one of the special tapered hobs, and Fig. 2 shows the teeth of a large worm-wheel being generated by a fly-cutter. In the latter case the worm-wheel has 92 teeth of 2 pitch and triple lead; the outside diameter of the wheel is 47½ inches and the face width 5½ inches. The cutting of the teeth in this wheel was completed in ten hours.

BICKNELL-THOMAS TAPPING CHUCK

The distinctive features of the friction-driven tapping chuck which has been added to the line of the Bicknell-Thomas Co., Greenfield, Mass., are the simplicity of the design and the compact form of construction which has been developed. The latter feature makes the chuck suitable for use on many machines where some types of tapping chucks are too cumbersome, a case in point being on certain types of multiple-spindle drills or tapping machines where the center distance between the holes is relatively small. The friction drive is adjustable so that sufficient power can be provided to drive the tap under normal working conditions; but if a hard

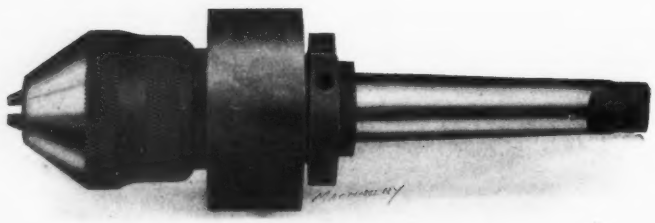


Fig. 1. Bicknell-Thomas Friction-driven Tapping Chuck

spot in the work is encountered or some other abnormal condition arises, the friction will slip before sufficient strain develops to break the tap. Another class of work on which this adjustable friction drive is of value is in setting up a machine for tapping blind holes. In such cases an error in judgment on the part of the operator is likely to result in driving the tap to the bottom of the hole and breaking it. With the Bicknell-Thomas tapping chuck such accidents are virtually impossible.

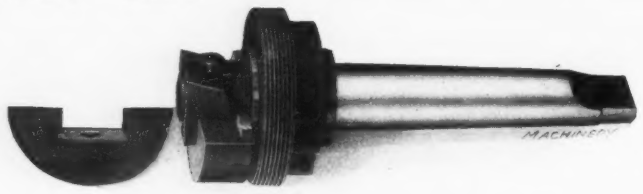


Fig. 2. Driving Mechanism of Bicknell-Thomas Chuck

Fig. 2 shows the driving mechanism of the Bicknell-Thomas chuck, from which it will be seen that the friction drive is provided by a split fiber disk which fits around a beveled center piece. A cylindrical member located under the jaws of the chuck fits over the split disk, and the two halves of the disk are forced against the inner surface of this part by drawing the beveled center piece down into the shank of the chuck. Thus provision is made for adjusting the radial position of the halves of the driving disk to give the necessary power for the size of tap being used. The adjustment of the frictions is made by turning the locking-nut at the back of the chuck. It will be evident from Fig. 3 that the chuck jaws are designed in such a way that they grip both the round shank of the tap and the squared portion at the end of the shank. These chucks are made in five different sizes known as Nos. 952 to 956, and the capacities of these tools are ⅛ to ¼ inch, 3/16 to ⅜ inch, ¼ to ½ inch, 5/16 to ¾ inch, and 9/16 to 1 inch, respectively. They are made with an assortment of Morse taper shanks or straight shanks of various diameters to meet the requirements of different machines on which this tapping chuck can be used.

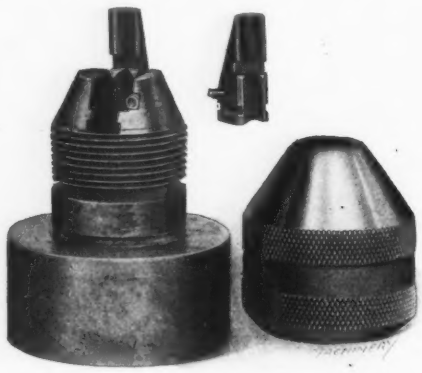
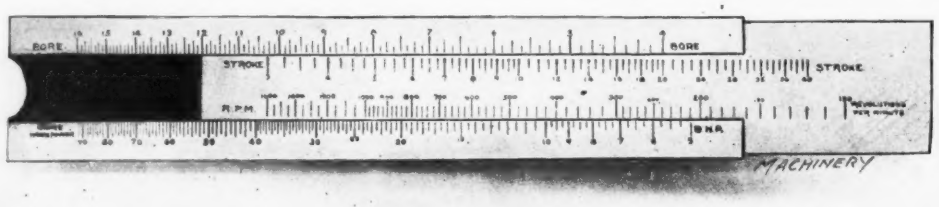


Fig. 3. Jaws of Chuck showing Provision for holding on both Round Shank and Squared End of Tap

BARRETT "GASPOWRULE"

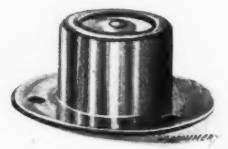
The accompanying illustration shows a slide-rule known as a "gaspowrule" which has been developed by D. O. Barrett, 802 S. McDonald St., Lima, Ohio, for use in determining the approximate horsepower developed by four-cycle gas and gasoline engines. The rule also gives quite satisfactory results for two-cycle semi-Diesel oil engines. This rule has been developed from data obtained in making a great number of engine tests, and while it is not claimed that the results are absolutely accurate, it affords a means of rapidly comparing the results obtained from various sizes of engines.



Barrett "Gaspowrule" for calculating Power developed by Four-cycle Gas and Gasoline Engines

E. G. SMITH POCKET LEVEL

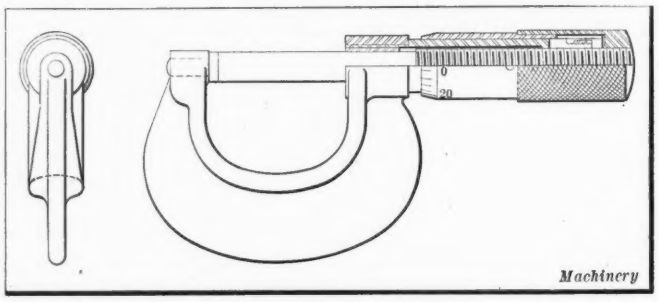
The No. 2 pocket level which forms the subject of this description is known as the "Tampa" which-way level, and is a recent product of E. G. Smith, 315 West Park Ave., Tampa, Fla. This tool consists of a circular vial which is fastened in a steel casing 1 inch in diameter by ⅜ inch high. There are three ⅛-inch holes in the base of the casing for fastening the level to a larger surface. Levels of this type may be provided with a polished brass base either 1½ inch or 2½ inches in diameter. These bases are graduated at 50 to 100 spaces respectively, to facilitate pointing out in which direction the work is out of level; and the levels are carefully finished and nickelplated, so that to use the phrase of the manufacturer "they are attractive enough for a watch charm."



E. G. Smith No. 2 Which-way Level

REED & PRINCE MICROMETER

The micrometer caliper which has recently been placed on the market by the Reed & Prince Mfg. Co., Worcester, Mass., follows the general lines of the micrometer calipers which have been manufactured by this concern for the past five years; but the new tool comprises several noteworthy improvements. The anvil is fixed instead of being adjustable, and this change has made it possible to reduce the depth of the frame at the anvil so that the micrometer can be used in narrower places. Adjustment for wear is made by means of a two-part thimble; the knurled part of this thimble is permanently attached to the spindle and the sleeve or plain part can be rotated, while the spindle and anvil are in contact with each other, until the zero mark on the thimble corresponds with the zero graduation on the barrel. The two parts of the thimble are a friction fit, and when assembled together they are locked in such a way that the spanner wrench provided for this purpose must be used when making the adjustment. There is no danger of the setting being accidentally changed. This extremely simple adjustment is easily and accurately made and the same spanner wrench that is used for adjusting the sleeve is also employed for regulating the tension nut. A hardened bushing is pressed into the frame to guide the spindle; and this bushing is ground and lapped to the required size. The spindle is taper-threaded and locked into the thimble in such a way as to secure a rigid joint, the end being riveted over to give additional strength.



Improved Reed & Prince Micrometer

LINDGREN HIGH-SPEED BENCH DRILL

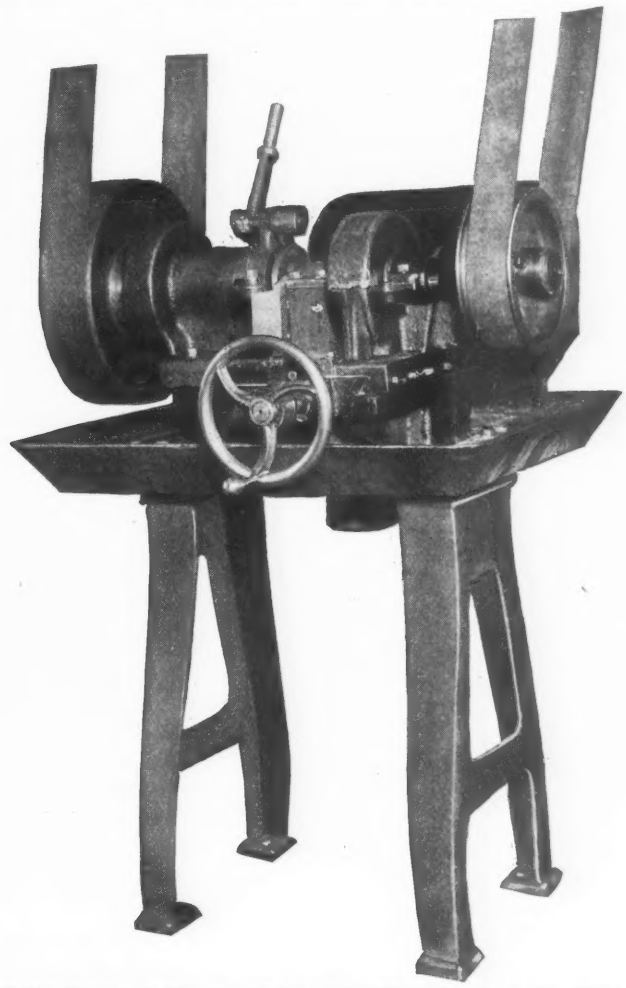
The F. W. Lindgren Co., Rockford, Ill., has recently placed on the market a 13-inch high-speed bench drill which is suitable for all kinds of light drilling and is particularly adapted for tool and die work. To provide for operation at high speed, all the bearings are bronze bushed and equipped with ring oilers, which provide constant lubrication; when worn, the bushings can be readily replaced. The crown gear is fitted with a thrust bearing at the end of the hub, and a fiber washer prevents the escape of oil. The spindle is equipped with ball thrust bearings, and the sleeve is graduated in inches. The capacity of the machine is for drills up to $\frac{5}{8}$ inch.

F. W. Lindgren 13-inch High-speed Bench Drill

The principal dimensions of this drill are as follows: Height, 37¾ inches; maximum distance from spindle to base, 21 inches; maximum distance from spindle to table, 15 inches; diameter of column, 3½ inches; size of table, 9 by 11 inches; hole in spindle, No. 1 Morse taper; width of belt on cone pulleys, 1¾ inch; width of belt on tight and loose pulleys, 1½ inch; floor space occupied, 32 by 12 inches; and net weight of machine, 155 pounds.

HOLDEN-MORGAN PLUG MILLER

The Holden-Morgan Co., Toronto, Canada, has recently added to its line a machine for use in turning the gas check plug and milling the thread for high-explosive shells. In addition to the two operations referred to, the machine also provides for facing the plugs. The entire operation is performed at a single chucking of the work, and the time required to completely mill a plug is from two to three minutes. The machine is equipped with an oil pump, quick-acting collet and automatic stops for all the feed movements. The method of operation is so simple that satisfactory results can be obtained with unskilled labor. The A. R. Williams Machinery Co., Ltd., 64-66 Front St., West, Toronto, Canada, has the exclusive sales agency for the machine.



Holden-Morgan Machine for turning and milling Thread on Gas Check Plugs for High-explosive Shells

AMERICAN HIGH-SPEED SILENT CHAIN

The characteristic feature of the high-speed silent chains manufactured by the American High Speed Chain Co., Indianapolis, Ind., is the simplicity of the design. These chains are

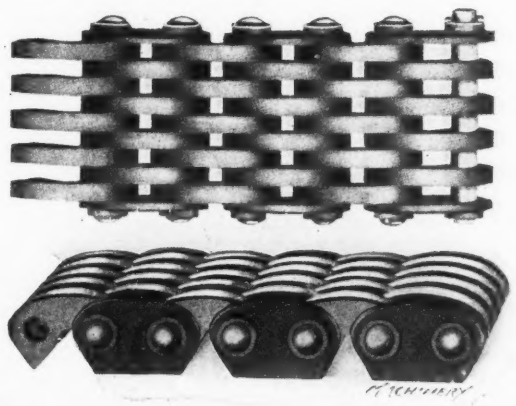


Fig. 1. American Silent Chain—note the Three-part Construction

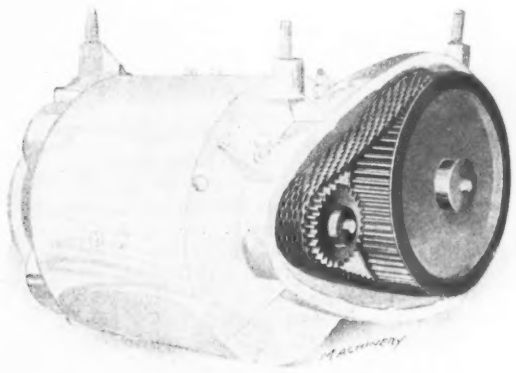


Fig. 2. Application of the American Silent Chain

composed of three parts, namely, the links, connecting pins and washers, which are made of chrome-nickel steel having a tensile strength of 170,000 pounds per square inch. The links are of sufficient thickness to enable them to be casehardened to provide greater strength and durability, and at the same time allow the metal in the interior portion of each part to be left in its natural condition of toughness, with the result that the chain possesses the desirable property of flexibility. The pins and washers are also casehardened, and are said to be practically indestructible. The pins are not held stationary; they are free to rotate, and, therefore, distribute the wear around the entire surface.

The links are accurately machined in relation to the pin-holes and pitch-line, and the angle of the links is 60 degrees, which experience has shown to be well suited for maintaining the proper relation between the links and the sprockets over which they run. The links are fitted perfectly against the sprocket teeth and make contact without friction, so that noise is virtually eliminated. This correct meshing of the chains and sprockets, and the distribution of the load over a large number of teeth, is constant, regardless of the wear which may have developed from long usage. This condition is effected by an automatic adjustment which provides for assuming a correspondingly large pitch diameter of the wheels as the teeth or bearings wear and the chain stretches.

W. A. WHITNEY CHANNEL IRON PUNCH

The W. A. Whitney Mfg. Co., Rockford, Ill., has recently added to its line of hand-operated metal punches a portable channel iron punch of the same general construction as the No. 2 punch manufactured by this company. All parts of the new channel iron punch are interchangeable with the standard No. 2 punch, which enables shops to interchange punches, dies, etc., between the two tools. The capacity of the channel iron punch is for holes up to ¼ inch in diameter through iron ¼ inch in thickness; and it is capable of reaching to the center of a 4-inch channel iron with 1½-inch flanges. This is said to be the only portable channel iron punch on the market.

NEW MACHINERY AND TOOLS NOTES

Portable Magnetic Separator: Cutler-Hammer Clutch Co., Milwaukee, Wis. A portable outfit for use in various departments of a factory for removing particles of iron from brass scrap.

Hanger Insert for Concrete: Diamond Expansion Bolt Co., 90 West St., New York City. Two forms of bolts for use in concrete buildings, to provide for securing pipe hangers and other supports to the walls, ceiling or floor.

Engine Lathe: McCoy-Brandt Machinery Co., House Building, Pittsburg, Pa. Heavy-duty engine lathe intended for use in machining shrapnel shells. The machine is built with a swing of 18 inches and an 8-foot bed. There are six changes of speed. The carriage is equipped with a six-hole turret or a compound rest as desired.

Screwdriver with Rubber Covered Handle: H. D. Smith & Co., Plantsville, Conn. A screwdriver which has a handle covered with hard rubber so that a very firm grip is secured. In addition, the rubber cover constitutes a safety feature when the screwdriver is used on electrical apparatus. The tool measures 11¼ inches in length.

Shell-Band Turning Lathe: Jenckes Machine Co., Sherbrooke, Canada. A machine particularly adapted for turning the copper rifling bands for use on the larger sizes of high explosive shells. The turning operation is performed by roughing and finishing tools which are carried at the front and back of the cross-slide, respectively.

Concrete Drill: Diamond Expansion Bolt Co., 90 West St., New York City. An improved form of drill for use in brick or concrete. This is an improved design of the drill formerly manufactured by this company, the chief improvement consisting of the provision of an adjusting screw for regulating the power of the blow delivered to the drill.

Bar Bending Machine: Wallace Supplies Mfg. Co., Chicago, Ill. A machine adapted for heavy bending operations such as bending 1¼-inch twisted reinforcing bars to any desired angle or to a U-shape. The machine is also suitable for bending ordinary square, round or flat iron bars; and can be arranged for bending channels, T-irons, etc.

Moving Picture Outfit: The Optigraph Co., Chicago, Ill. A portable moving picture projector which is particularly adapted for industrial purposes, such as showing prospective purchasers the operation of machine tools in which they are interested. The apparatus can be operated from an ordinary electric light socket and uses standard sized films and slides.

Work Cabinets: Berger Mfg. Co., Canton, Ohio. A line of pressed steel work cabinets developed for the purpose of providing secure and convenient storage facilities for dies, tools, blueprints, etc. The cabinets are substantially constructed of pressed sheet steel, and equipped with a heavy top which can be used as a bench for laying out work.

Special Punching Machine: Cleveland Punch & Shear Works Co., Cleveland, Ohio. A special punching machine of unusual size, which was designed and built for the Bethlehem Steel Co. for use in performing all punching operations involved in the fabrication of heavy steel sections. The machine has a capacity for punching eight 1-inch holes in 1-inch material.

Multiple Spindle Drill: Gem City Machine Co., Dayton, Ohio. A 44-spindle machine built for the purpose of drilling and countersinking holes in aluminum automobile retaining strips. Each of the spindles is equipped with a combination drill and countersink, and the machine is constructed in such a way that any number of spindles up to the full capacity may be used.

Multiple-spindle Drilling Machine: National Automatic Tool Co., Richmond, Ind. A ten-spindle drill which is known as the standard No. 13 machine of the line manufactured by this company. The same type of drill is also made with various numbers of spindles according to the requirements of different users. Both the table and drill head are adjustable on the column.

Tapping and Countersinking Machine: Poese Machinery & Mfg. Co., Cleveland, Ohio. An automatic machine designed for tapping either "blind" or through holes up to ¼ inch in diameter. The machine taps the hole to the required depth, reverses and backs out the tool without requiring the operation of a hand lever or foot treadle. The weight of the machine is 125 pounds.

Saw Setting Device: Hunter Saw & Machine Co., Pittsburg, Pa. A device for setting the teeth of inserted-tooth saws. It is a generally known fact that in order to obtain the best results with saws of this type, the teeth must be set at exactly the same height. With the device developed by the Hunter Saw & Machine Co., all teeth can be set to an accuracy of 0.001 inch.

Slitting Machine: Charles Leffler & Co., 61 Clymer St., Brooklyn, N. Y. A machine for slitting metal sheets into strips. It is furnished with automatic power feed and a grinding attachment for sharpening the cutters. The cutters are 6¾ inches in diameter and double edged. The machine represents an improved design of the slitting machine formerly manufactured by this concern.

Sheet Metal Forming Machine: C. L. Frost & Son, Grand Rapids, Mich. A rolling machine for use in forming strips of sheet metal into various shapes. The capacity of the machine is for forming from 4000 to 4500 feet of strip metal per hour. The coil of material to be formed is placed on a reel at one end of the machine, from which it is drawn between the forming rolls as required.

Countershaft: Cincinnati Tool Co., Norwood, Cincinnati, Ohio. A "single-pull" countershaft in which the oscillating lever to which the cord is attached is kept in position by a compression spring which locks the shifter bar at the end of each stroke. A single pull of the cord stops or starts the machine; and, of course, the height of the ceiling does not affect the operation of the countershaft.

Sanitary Water Cooler: L. G. Stebbins, New London, Conn. A drinking water cooler particularly suited for shop use. The ice is placed in a separate compartment at the top of the cooler and the water melted from it runs down through a pipe into a false bottom, from which it is drawn off. The ice chamber is surrounded by an air-tight compartment which prevents the ice melting too rapidly.

Shrapnel Shell Grinding Fixture: Ransom Mfg. Co., Oshkosh, Wis. A fixture designed for use in removing the center bosses from shrapnel shells by grinding. This fixture is used in connection with a Ransom disk grinding machine, and enables this work to be done very rapidly and accurately. In finishing shells in this way, the work is placed in a V-block and does not require to be clamped.

Belt Shifter: Diamond Clamp & Flask Co., Richmond, Ind. This belt shifter has been developed to reduce the possibility of accidents in shifting belts. It is applicable to any type of countershaft which has a tight and loose pulley; but it cannot be used on a countershaft that has a reverse pulley. This shifter is made in five different sizes for handling belts ranging from 1¼ to 6 inches in width.

Autogenous Welding Table: Cave Welding & Mfg. Co., Springfield, Mass. A universal table designed to facilitate repair welding and manufacturing operations in which weld-

ing has to be done. The table is particularly suitable for use where it is desirable to strap the work down, and then alter the position of the table, as may be required, without loosening the straps until the welding is finished.

Heavy Wire Drawing Machine: Morgan Construction Co., Worcester, Mass. A machine developed for use in drawing large wire of round, square or hexagon sections. The accuracy of the product turned out in this way enables the stock to be handled in the gripping dies of automatic forming machines which require a smooth, clean bar of accurate size. The capacity of the machine is for drawing wire in sizes up to 1¼ inch in diameter.

Saw Tooth Grinding Machine: Huther Bros. Saw Mfg. Co., 1108 University Ave., Rochester, N. Y. A special type of grinding machine for use in sharpening saws of the inserted-tooth type which are used for cutting off bar stock and structural material. The grinding wheel can be set for various tooth angles. In operation, the saw is mounted on an adjustable table which is carried by the base on which the grinding wheel is mounted.

Multiple-spindle Drill: National Automatic Tool Co., Richmond, Ind. A No. 12 machine which is equipped with the company's regular type of attachment for throwing in or disengaging the power feed, and for making other adjustments. Two changes of power feed are provided, and there are four changes of speed ranging from 350 to 1020 revolutions per minute. The machine is equipped with a tapping attachment. Its weight is 2000 pounds.

Annealing Boxes: Pittsburg Annealing Box Co., Pittsburg, Pa. Reinforced boxes designed to withstand the intense heat employed in annealing furnaces. For this purpose forged supports or pedestals are provided which are riveted to the bottom and edges of the annealing boxes at the points subjected to the greatest strains. The pedestals support the boxes at a sufficient height from the floor of the furnace to permit a complete circulation of the hot gases all around the boxes.

Filing Machine: Robinson Tool Works, Inc., Waterbury, Conn. A No. 2½ machine which has been developed to meet the demand for a filing machine of larger capacity than has formerly been made by this company. Either regular files or special files with ¼-inch shanks can be used in the machine. The table is adjustable for any angle of clearance in the die which is to be filed, and has a working surface 8 inches square. The machine makes 600 strokes per minute and weighs 50 pounds.

Shell Banding Press: Chapman Double Ball Bearing Co. of Canada, Ltd., Toronto, Canada. A machine for use in compressing the copper rifling bands onto shrapnel shells. This press is of about the standard design; it has an 8-inch ram, a stroke of 8 inches, and a pressure capacity of 75 tons. The die is made with eight wedge-shaped fingers which are forced against the copper band when the ram is raised, by means of tapered surfaces on the outside of the wedges which engage a hardened steel ring secured to the top of the press.

Plain Turning Lathe: Earle Gear & Machine Co., Stenton and Wyoming Aves., Philadelphia, Pa. A heavy-duty, plain turning lathe built especially to meet the requirements of machining shrapnel and high explosive shells. The design has been developed along extremely simple lines and particular attention has been paid to securing a very rigid machine. The bed is 7 feet long and is cast integral with the headstock. Eight spindle speeds are available and there are twenty-four combinations of feed and speed.. The machine is made in three sizes of 18, 20, and 24 inches.

Precision Computer: Computer Mfg. Co., 25 California St., San Francisco, Cal. A circular slide-rule which has been developed by Louis Ross, and which is manufactured by the company referred to. The instrument consists of a graduated dial which rotates under a slotted cover, a floating guide, and a slide mounted beside the slot. The operation of the dial gives results to an accuracy of five significant figures. The slide carries a miniature of the dial and may be used separately to obtain an accuracy of three figures; it is used in connection with the dial to check the result obtained and to locate the decimal point.

* * *

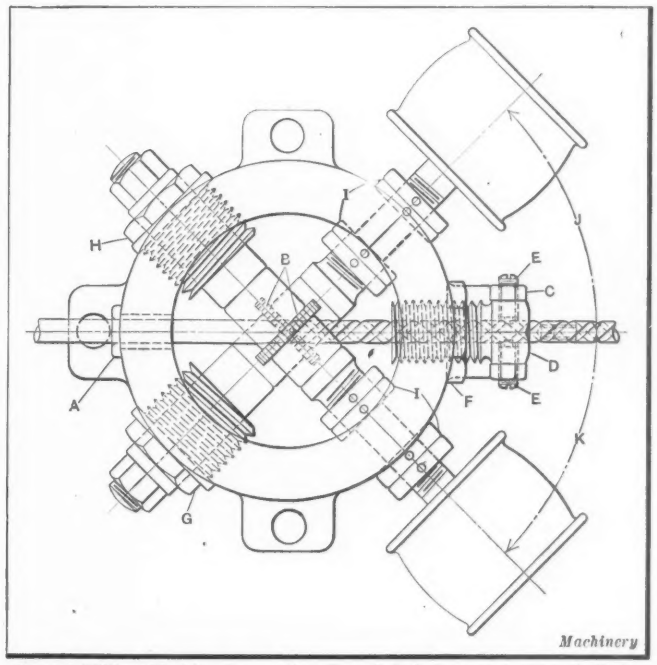
Years ago builders of transmission machinery turned shafting for their customers, but now the manufacture of turned shafting is no longer a profitable part of the business. Power transmission machinery concerns make hangers, couplings, clutches, pulleys, sheaves, etc., and furnish turned or cold-rolled shafting that is bought from the regular shaft making concerns. Turning shafting is somewhat like steel mill production, being a tonnage proposition. The power transmission concerns generally buy their shafting and sell it at a small profit to their customers when filling orders for power transmission equipment.

MACHINE FOR MILLING SPIRAL GROOVES

BY GEORGE WERNER, JR.*

We recently received an order which required two spiral grooves 1/16 inch deep by ⅛ inch wide, with a lead of 1 inch, to be milled in rods ⅜ inch in diameter. This work did not have to be very accurate, a tolerance of 0.005 inch being allowed. We used the milling machine and dividing head for cutting the grooves in the first lot of rods, but this method required a separate cut to be made for each of the two grooves in the rod, and consequently took considerable time. To enable the work to be handled more rapidly, I designed a special machine for milling the two spiral grooves simultaneously, thus greatly increasing the rate of production.

When using this machine it is first necessary to make a pilot or "leader" from a piece of rod 6 or 8 inches long and of the same diameter as the work. This leader has two spiral grooves cut in it of the same lead that it is required to mill, and is threaded on one end to enter a tapped hole in the end of the work. In assembling the machine, the leader is passed through the guide bushing *A* and moved past the milling cutters *B* to engage the nut *C* on the machine, which controls the lead of the spiral grooves that are milled in



Special Milling Machine for cutting Two Spiral Grooves in ⅜-inch Rods

the work. The leader is now set so that the rod to be milled will come into contact with the cutters; this rod is then screwed onto the leader and a clamp is attached to a rod at a point beyond the machine, so that it can be turned by hand, very little effort being required.

It will be evident that as the rod is turned, it is also drawn past the cutters through the connection of the threaded leader in the nut *C;* and that after the pilot has passed through the nut the grooved rod enters the nut and acts as its own leader. When pushed to its full capacity, the machine will cut the spiral grooves at the rate of 6 inches of rod per minute, but under ordinary operating conditions the rate of production is about 3 inches of rod per minute. The machine is so simple that any boy of average intelligence can be taught to run it. When the milling of the spiral groove in the rod is completed, the rod is cut up into pieces of the required length ready for use.

Having referred to the work done by the machine, a brief description will now be given of its design and construction. The arrangement of the guide bushing *A*, milling cutters *B*, and lead nut *C* have already been referred to. It will be seen that the nut *C* is carried at the end of threaded bushings *D*. The lead nut is formed by means of set-screws *E* which have pilots at their ends that are of the proper size

* Address: 582 S. 10th St., Newark, N. J.

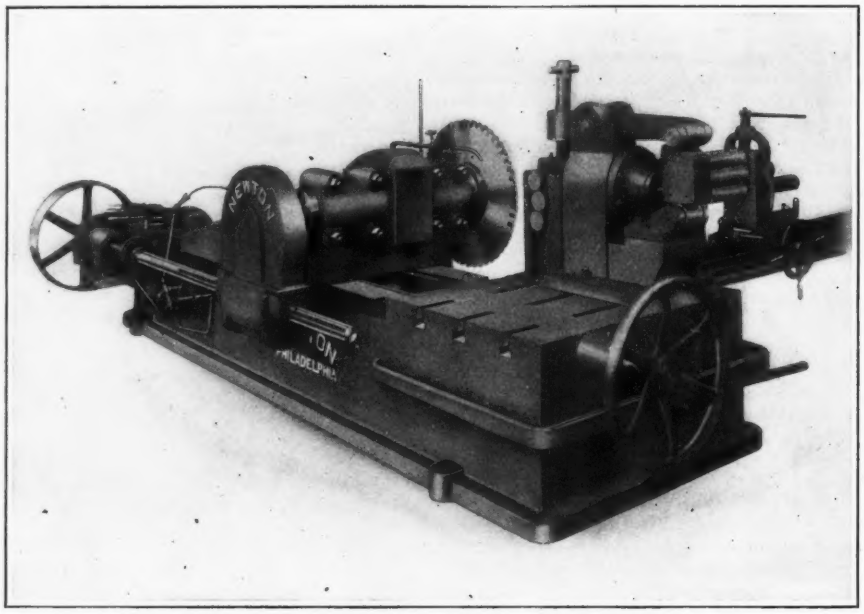
to engage the grooves in the rod without any lost motion. The set-screws *E* are provided with lock-nuts, as shown; and a lock-nut *F* is also provided to hold the threaded bushing *D* in the required position. The outboard bearings *G* and *H* in which the spindles are carried are threaded into the frame of the machine so that they can be readily removed when it is necessary to change the cutters. It will also be noticed that adjusting collars *I* are provided at the pulley ends of the spindles. The angles *J* and *K* are equal to the spiral angles of the grooves being milled.

* * *

CUTTING OFF SHRAPNEL BLANKS ON NEWTON COLD SAWS

The demand which has been created by the manufacture of shrapnel and high-explosive shells in this country for machines to cut off short lengths from bar stock ranging from 3 to 9 inches in diameter, led the Newton Machine Tool Works, Inc., Philadelphia, Pa., to make a special study of the requirements which are imposed upon machines employed for this purpose. Investigations were conducted in plants of American and Canadian manufacturers and special tests were run off in the Newton Works. The data gathered from these sources has made possible the standardization of equipment for cutting off one, two, three, five and any other number of bars at a single operation.

The machine shown in the accompanying illustration is arranged for cutting off three blanks from three bars 3⅝ inches in diameter at a time; and although much higher feeds are possible for demonstration purposes or even for continuous operations over considerable periods of time, the rate of feed recommended for regular work is 2 inches per minute when cutting three bars simultaneously, and 2½ inches per minute when cutting one bar at a time.



Newton Cold Saw equipped with Multiple Work-holding Fixture for cutting off Shrapnel Shell Blanks

In order to increase the rate of production by decreasing the loss of time which formerly occurred in setting up work in the machine, the use of a stock feeding trolley is recommended. Such an equipment acting in connection with the Newton air-controlled clamp with which the machine is provided, saves a considerable amount of time which would otherwise be lost between cutting operations, and also reduces the number of operators required to run the multiple machines. The rates of feed which have been previously referred to are calculated for constant service during twenty-four hours per day; and in determining these rates, consideration has been given to the cost of maintenance—especially in regard to saw blades. In the Newton cold saws, all bearings are bronze bushed, the driving worm-wheel is made of phosphor-bronze, and the worm is of hardened steel with a roller bearing to receive the thrust. The machine is provided with a lubricant pump and piping, and all gears are covered to conform with the most stringent safety laws.

* * *

Proper heat-treatment makes possible the use of gears of less heavy sections than would otherwise be required, and while this may not be necessary to save weight, it may be desirable to economize in space. The greatest advantage of heat-treated gears, however, is their long life, which means the elimination of repairs and replacements.

NEW IDEAS IN MECHANICAL EDUCATION

A number of new ideas in engineering and trade education have been inaugurated during the last few years, many of which give promise of considerable success. The most important of these is the "cooperative" engineering course at the University of Cincinnati. In order to give the student of engineering a theoretical and at the same time a practical training, a course of six years' study has been adopted. During this period the students work alternate weeks in the shops of the city and in the class-rooms of the university. The students are arranged in pairs, so that when one of them works in the shop, the other receives class-room instruction. The next week the two students will change places. In this way, the practical and theoretical training is carried on simultaneously, with very satisfactory results. During the summer months the students work the entire time in the shops. A system of this type, of course, can be instituted only in large industrial centers, where there are great numbers of shops, each of which is willing to take one or more pairs of students for training. Possibly there is not another city in the United States so well fitted for this type of engineering education as is Cincinnati. Nevertheless, the method must be considered as showing the most advanced idea in engineering education at the present time.

A similar plan adapted to mechanical trade education has been adopted by the high schools of Fitchburg, Mass., the idea having been patterned after the Cincinnati plan. In this case, the boys who wish to be apprenticed in the shops of the city are given an opportunity to acquire training in the shops at the same time that they receive a high school education. The course here is four years, the first of which is spent entirely in the school, while the next three years are spent one week in the shop and one week at the high school, the boys being arranged in pairs for this purpose and alternating with each other.

In Worcester, Mass., a distinct step toward better trade education also has been taken. The Worcester Trade School, the first building of which was opened in the early part of 1910, is intended to give a complete trade training to boys and young men between fourteen and twenty-five years of age. Instruction is offered in machine work, toolmaking, pattern making, power plant engineering, and a number of other trades. Each course comprises four years, and the hope is that when a boy has finished his course in this trade school, he will be able to obtain work in his trade at journeyman's wages. A complete shop equipment is maintained for this purpose, and the work, so far as possible, is conducted along commercial lines. It has been stated by Worcester manufacturers that, if anything, the boys who have been trained for four years in the trade school are worth more, at the end of that time, than those who have been regularly apprenticed in the shop. This, of course, is due to the fact that when apprenticed in the shop, the boy is often kept on the same class of work for long periods of time, whereas in the trade school he is given an opportunity to broaden his knowledge, on account of the greater diversity of the work which he is called upon to do.

A new idea in engineering laboratories has also been developed recently. The old method of equipping an engineering laboratory at a school of technology was to buy, or to obtain as gifts, a variety of machines, equip the plant and testing room, and give the students year after year the same stereotyped course of practice and study. That was a convenient and simple method, as the instructor met few new problems, but after a few years the equipment became obsolete, and the students seldom obtained a knowledge of the latest practice. The new idea is exemplified in the Mason Laboratory of the Sheffield Scientific School at Yale University, and aims at a constant rotation of the equipment. No machines are bought—in fact, they are not even accepted as gifts, a radical departure in the practice of an endowed college or university; but Prof. Breckenridge, who is in charge of the mechanical engineering department, accepts with appreciation the *loan* of any machines—from electrical machinery and steam engines to machine tools and motorcycles—for experimental purposes, in order to carry out—by their aid—a number of tests, covering a period of several months. Then the machines are returned to the manufacturers in perfect condition, and other tools and machines take their place.

It is easy to see how great are the advantages of this system over the old permanent equipment system. In the first place, the students have an opportunity to familiarize themselves with a much greater variety of machinery during their term at college. They constantly see new things; their interest is increased; they do not get an opportunity to look upon their education as a fixed quantity—they become more aware of their limitations—a most important thing for a college student; and, last but not least, their whole education is more complete, and more in harmony with conditions in the outside world.

There is also another important aspect to the system of constantly changing the equipment. The effects upon the professors and instructors themselves must be very valuable. They are in this way enabled to obtain first-hand knowledge of new developments, and they are forced to keep pace with the progress of actual practice. The system increases their interest in their work, as it eliminates much of the set routine of the same tests being made over and over again, and the same machines—often old—being used constantly for demonstration purposes. It presents to them new problems which must be solved—thus preventing them from getting into a rut. Briefly, it ties the school and practical engineering closely together, and it is to be expected that the plan will be adopted by many more engineering educational institutions in the future.

* * *

In investigations to determine the effect of relative humidity on oak-tanned leather belts, made by Prof. William W. Bird and Francis W. Roys, of Worcester, Mass., as reported in a paper before the American Society of Mechanical Engineers, the general conclusions arrived at are as follows:

1. If a belt be set up at low relative humidity, slipping will probably occur if the humidity increases to any great extent, especially if accompanied by a rise in temperature.

2. If a belt be set up at high relative humidity, excessive pressure on the bearings and stretching of the belt will result from a decided decrease in humidity, especially if accompanied by a fall in temperature.

3. If a belt be set up at a medium relative humidity, the tensions will not be excessive at lower humidities, nor will there be any great danger of slipping at higher humidities, unless accompanied by excessive temperature changes; in other words, the factor of safety in the ordinary belt rules is sufficient to take care of the effect of changes in the relative humidity if the set-up be made at a medium per cent of relative humidity.

4. If a belt be set up at any relative humidity with a spring or gravity tightener, a load 50 per cent greater than the standard can be transmitted at either high or low humidity without danger of stretching the belt, slipping or excessive pressure on the bearings.

THE ELECTRIC INCANDESCENT LAMP

October 21 will be commemorated as the thirty-sixth anniversary of the invention of the electric incandescent lamp by Thomas A. Edison. Carbonized cotton thread and narrow paper strips were used first for the filaments, but were too fragile and short-lived to be commercially used. A search for grasses and fibers throughout the world resulted in the discovery of the value of Japanese bamboo for the purpose, and carbonized bamboo was the only substance used for about ten years. This was followed by the "squirted" filament, employing carbonized cellulose in one form or another, next the metallized carbon filament, then the pressed tungsten filament and finally the special form of drawn tungsten wire used in the modern Mazda lamps. Working down from a consumption of four or five watts of electrical energy per candlepower in the carbon filament lamps to the standard a few years ago of 3.10 watts per candlepower, the Mazda lamp has brought this down in about five years to about one watt. In the larger sizes of Mazda gas-filled lamps, the reduction in current consumption has reached the low level of nearly a half-watt per candlepower. And no one can forecast the marvels that are yet to be unfolded in electric lamps and methods of lighting. Light without heat is the ideal, but that is still far off. The electric incandescent lamp of today contains the cheapest form of filament that has ever been produced, but some day it will be better and cheaper still.

* * *

An interesting paper has been read before the Academy of Sciences, in Paris, describing experiments undertakeh to determine the velocity of the waves used in wireless telegraphy. These experiments were undertaken first between Paris and Toulon in France, and finally between Paris and Washington. The methods employed to measure the time enabled the measurement precisely of an interval of 0.00001 second. It was found that the wireless telegraphy waves are carried along the surface of the earth with a velocity slightly less than that of light.

* * *

PERSONALS

H. C. Elliott, vice-president of the Marshall & Huschart Machinery Co., Chicago, resigned, his resignation taking effect September 1.

R. S. Bryant, for many years consulting engineer of the Standard Welding Co., Cleveland, Ohio, has been appointed factory manager in charge of all manufacturing.

H. L. Wittstein, efficiency engineer with the Knox Motors Co., Springfield, Mass., has resigned to take the position of assistant to the management of the Standard Fuse Corporation of Paulsboro, N. J.

L. F. Hamilton, advertising manager of the National Tube Co., Pittsburg, Pa., was awarded a gold medal for planning the exhibits of the National Tube Co. at the Panama-Pacific International Exposition in San Francisco.

L. S. Neuschul, engineer and director of M. Mett Engineering Co., Petrograd, Russia, is making a trip through the Middle West for the purpose of obtaining a representation for a few more lines of machine tools in Russia.

B. J. Morrison, mechanical engineer and general manager of the National Supply & Equipment Co. of Philadelphia, Pa., is in Europe on a three to five months' business trip, acting as consulting engineer for some American concerns.

A. B. Hazzard, president of the Falcon Motor Truck Co. of Detroit, Mich., has been appointed general works manager of the Hall Switch & Signal Co., Garwood, N. J. Mr. Hazzard was for ten years general manager of the J. Morton Poole Co., Wilmington, Del.

W. S. Hardy, for the past eleven years connected with the Diamond Rubber Co. and the B. F. Goodrich Co., and lately in charge of the sales of their mechanical rubber goods division, has been appointed sales manager of the Boston Belting Co., Boston, Mass., manufacturer of mechanical rubber goods.

A. B. Howard, for many years connected with the New York office of the American Express Co., 65 Broadway, has sailed for Buenos Aires to establish the initial South American office of the American Express Co., where Mr. Howard, as manager of the South American department, will make his headquarters.

John J. Eberhardt, foreman with the Simonds Mfg., Co., has been promoted to the position of superintendent of the Fitch-

Simple Control—

For Easy Operation

That's characteristic Brown & Sharpe design—simplifying and centralizing the control so that operation is easy and natural. Every handwheel and lever is located where an operator can get at it without reaching. Speeds and feeds are quickly controlled from a *single point*. Through this mechanism an almost universal range of independent speeds and feeds can be instantly secured. The two levers around the dial at the left of the machine marked "Head" and "Table" control the speed of the respective parts.

For Fast Production

This mechanism is an important factor. To begin with, the *most productive* combination of speed and feed can *always* be obtained, and obtained quickly too. Then the long lever behind the dial controls the entire machine, independent of the grinding wheel. By pressing down on this lever the table and headstock are *instantly* stopped—*one* simple motion does it. The work can be quickly removed, another piece put in, the lever pulled back, and the machine is again in operation. Non-productive time between grinding is thus reduced to a minimum.

For Uniform Results

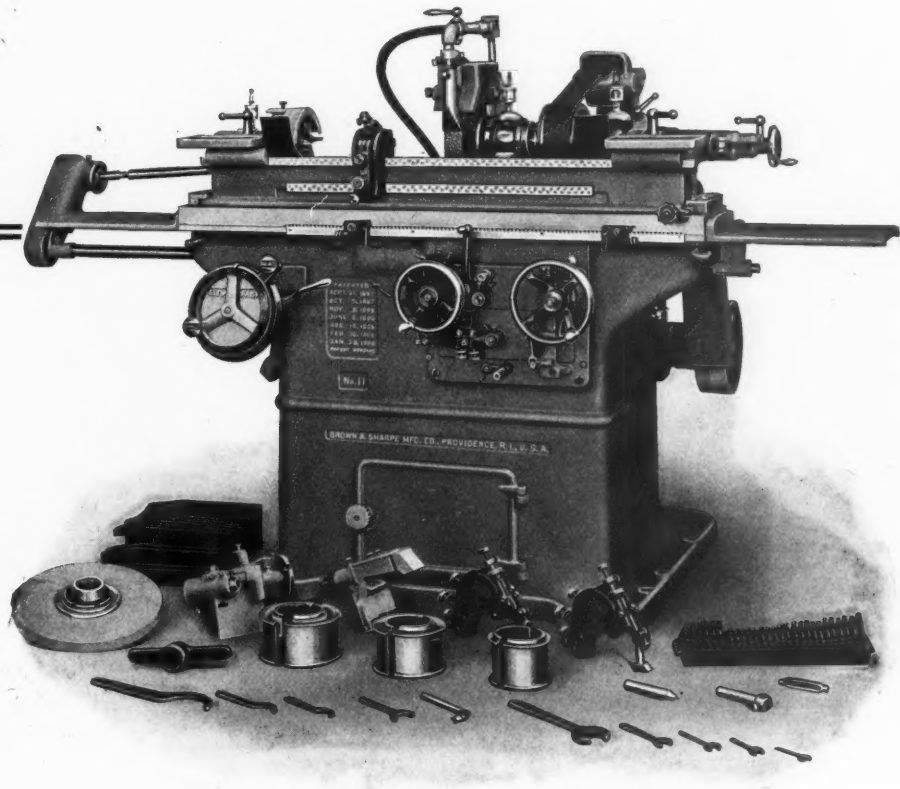
in the quality of work and cost of production you have exactly the required features in Brown & Sharpe machines. When a job is done under conditions that give satisfactory production the natural thing to do when that job comes in again is to duplicate those conditions.

That's very easy with our variable speed mechanism. If slight variations are necessary to meet some new condition the combination of speed and feed can be varied to suit. The best working conditions are always available, keeping costs low and uniform.

Brown & Sharpe Mfg. Co.,

OFFICES: 20 Vesey St., New York; 654 The Bourse, Philadelphia, Pa.; 626-630 Washington Blvd., Chicago, Ill.; 305 Chamber of Commerce Bldg., Rochester, N. Y.; Room 419, University Block, Syracuse, N. Y.

REPRESENTATIVES: Baird Machinery Co., Pittsburgh, Pa., Erie, Pa.; Carey Machinery & Supply Co., Baltimore, Md.; E. A. Kinsey Co., Cincinnati, O., Indianapolis, Ind.; Pacific Tool & Supply Co., San Francisco, Cal.; Strong, Carlisle & Hammond Co., Cleveland, O., Detroit, Mich.; Colcord-Wright Machinery & Supply Co., St. Louis, Mo.; Perine Machinery Co., Seattle, Wash.; Portland Machinery Co., Portland, Ore.



No. 11 Plain Grinding Machine

This representative of our line, shown above, in addition to being equipped with the feature just described is entirely self-contained, resulting in a more efficient drive, the practical elimination of overhead works, and adaptability to motor drive.

A high degree of accuracy in the work produced is assured by the true, carefully made alignments and the solid support and rigid construction which insure the maintenance of the original accuracy through years of service. And production—well, it's a very unreasonable demand in this direction that this machine cannot meet. In fact on some work the productive capacity of the machine is limited to the speed of the operator in handling the work. In this connection there's an advantage that cannot be over-emphasized. This machine is so handy, efficient, and smooth-running that an operator has no difficulty in maintaining maximum and uniform production throughout the day. There's no afternoon fatigue attendant upon the operation of these machines. Your operators will like them. So will your production men.

If your shop is not equipped with any of these handy machines get in touch with us and we will show you where we can reduce your grinding costs and keep them uniform. Descriptive literature free on request, also our booklet, "Points About Grinding Wheels and Their Selection."

Providence, R. I., U. S. A.

CANADIAN AGENTS: The Canadian Fairbanks-Morse Co., Ltd., Montreal, Toronto, Winnipeg, Calgary, Vancouver, St. John.

FOREIGN AGENTS: Buck & Hickman, Ltd., London, Birmingham, Manchester, Sheffield, Glasgow; F. G. Kretschmer & Co., Frankfurt a/M., Germany, V. Lowener, Copenhagen, Denmark, Stockholm, Sweden, Christiania, Norway; Schuchardt & Schutte, Petrograd, Russia; Fenwick Freres & Co., Paris, France; Liege, Belgium; Turin, Italy; Zurich, Switzerland; Barcelona, Spain; The F. W. Horne Co., Tokio, Japan; L. A. Vail, Melbourne, Australia, F. L. Strong, Manila, P. I.

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burg, Mass. shops of that company, succeeding Gifford K. Simonds. Mr. Eberhardt has been connected with the company for the past six years, having served as foreman in several departments. He was previously with the Iver Johnson Arms & Cycle Works of Fitchburg.

Benjamin G. Lamme, chief engineer of the Westinghouse Electric & Mfg. Co., has been named a member of the Naval Advisory Board by Secretary of the Navy Daniels. Mr. Lamme is a graduate of the Ohio State University. He entered the employ of the Westinghouse Electric & Mfg. Co. in the testing department in 1889; in 1900 he was made assistant chief engineer, and succeeded to the position of chief engineer in 1903.

J. A. Massel, special agent of the Department of Commerce, has been making a tour of American cities for the purpose of ascertaining the general interest in South American trade. He found lively interest in the subject, manufacturers generally expressing willingness to expend reasonable sums to lay the foundations for substantial trade relations in the South American field. Mr. Massel's headquarters are Room 409, Custom House, New York City.

Leo. T. Neidow and Frank G. Payson have opened offices in the Madison Terminal Bldg., 9 S. Clinton St., Chicago, Ill., under the name of Neidow & Payson, where they will conduct a general machinery agency. Mr. Neidow has been with the Niles-Bement-Pond Co. for the past eighteen years in the Chicago office. Mr. Payson was formerly with the Niles-Bement-Pond Co., and for the past four years was western representative of the Union Petroleum Co., Philadelphia, Pa., mineral lard oil department.

* * *

OBITUARIES

John C. Wood, for more than fifty years connected with the U. S. Government Armory at Springfield, Mass., died at his home in Springfield, September 10, aged eighty-eight years.

Edward W. Moore, formerly United States commissioner of patents and an expert in patent law, died at his home in Washington, D. C., September 6, aged sixty-three years. Mr. Moore was commissioner of patents from 1907 until 1913.

Samuel T. Davis, Jr., president of the Locomobile Co. of America, Bridgeport, Conn., died at his summer home at Fairfield, Conn., September 1, aged forty-two years. Mr. Davis was a founder and the first president of the National Association of Automobile Manufacturers which later became the Automobile Chamber of Commerce, of which he was a director He was a pioneer in automobile manufacturing.

COMING EVENTS

October 28-29.—Annual convention of the National Machine Tool Builders Association, Hotel Astor, New York City. Charles E. Hildreth, general manager, Worcester, Mass.

December 7-10.—Annual meeting of the American Society of Mechanical Engineers, New York City; Engineering Societies Bldg., headquarters. Calvin W. Rice, secretary, 29 W. 39th St., New York City.

SOCIETIES, SCHOOLS AND COLLEGES

University of South Carolina, Columbia, S. C. Catalogue 1915-1916, containing the calendar for the sessions 1914-1915 and 1915-1916, as well as an outline of the courses included in the curriculum of the university.

School of Mines and Metallurgy, University of Missouri, Rolla, Mo. Bulletin for March, 1915, from catalogue 1914-1915, giving the calendar for 1915-1916, and information on the courses in mine engineering, metallurgy, civil engineering and general science that this university offers.

Polytechnic Institute of Brooklyn, Brooklyn, N. Y. Catalogue of evening technical courses, 1915-1916. The courses comprise chemistry, civil engineering, electrical engineering and physics, mechanical engineering, mathematics, English, French, German, Spanish, history, economics and physical training.

Columbia University, New York City, has established a separate department of chemical engineering upon the same plane of importance in the Columbia graduate engineering school as mining, civil, electrical and mechanical engineering. The head of the new department will be Prof. M. C. Whitaker, who has been professor of chemical engineering at Columbia University for the past five years.

Wentworth Institute, Huntington Ave. and Ruggles St., Boston, Mass. Catalogue of the Wentworth Institute for 1915-1916. Two new courses have been added, the first being a one-year day trade course in forging, hardening and tempering, and the second a one-year day trade preparatory course intended for young men who wish to enter some one of the manufacturing industries. The Institute also offers for the first time the second year of its course in architectural construction. This course is for training building superintendents, specification men and constructionists for architects and building contractors.

NEW BOOKS AND PAMPHLETS

The Testing of Rubber Goods. 89 pages, 7 by 10 inches. 35 illustrations. Published by the Department of Commerce, Washington, D. C., as Circular of the Bureau of Standards No. 38.

Specific Heat and Heat of Fusion of Ice. By H. C. Dickinson and N. S. Osborne. 32 pages, 7 by 10 inches. Illustrated. Published by the Department of Commerce, Washington, D. C., as Scientific Paper of the Bureau of Standards No. 248.

A Study of the Quality of Platinum Ware. By George K. Burgess and P. D. Sale. 20 pages, 7 by 10 inches. Illustrated. Published by the Department of Commerce, Washington, D. C., as Scientific Paper of the Bureau of Standards No. 254.

Measurements for the Household. 149 pages, 7 by 9 inches. 62 illustrations. Published by the Department of Commerce, Washington, D. C., as Circular of the Bureau of Standards No. 55.

The purpose of this circular is to give information as to units, methods and instruments of measurement useful in household activities, and to describe the available means of assuring correct quantity of articles bought by weight and measure. The aim is to awaken appreciation of the importance of correct measurements in the daily life of the family.

The Modern Gasoline Automobile—Its Construction, Operation, Maintenance and Repair. By Victor W. Page. 873 pages, 5 by 7½ inches. 411 illustrations. Published by the Norman W. Henley Publishing Co., New York City. Price, $2.50.

This book is the 1916 edition of a work that has been noticed in these columns before. A 55-page supplement treating of the twelve-cylinder V-motor, eight-cylinder V-motor, new valve operating systems, Stewart vacuum fuel feed, electric self-starting principles, cantilever and underslung springs, tilting steering wheels, hydraulic brakes, etc., has been added which brings an already excellent work up to date, making it one of the most practical treatises on the modern gasoline automobile published.

Effective Business Letters. By Edward Hall Gardner. 376 pages, 5¼ by 7¼ inches. Published by the Ronald Press Co., New York City. Price, $2.

An enormous amount of business is done by correspondence, and it is highly important that business letters be clear, concise and accurate in statements. The book was written for those in business or who intend to enter business, its object being to supply in systematic form the principles embodied in the best modern business letters. It treats of the general principles of business correspondence, the importance of appearance and correctness, the make-up of the letter, paper and envelopes, printing, mistakes in language, how letters asking for information should be written, etc. As might be inferred, the principles are demonstrated with many examples of letters, offered as suggestions of form.

Practical Mechanics and Allied Subjects. By Joseph W. L. Hale. 228 pages, 4½ by 6¾ inches. 201 illustrations. Published by the McGraw-Hill Book Co., Inc., New York City. Price, $1, net.

This book is based on the author's appreciation of the needs of trade apprentice schools. Difficulty has been experienced in securing books suitable for these schools, and this work was compiled to meet these needs as the author saw them. It treats of forces, gravitation, center of gravity, density and specific gravity, screw threads, calculation of levers, pulleys (block and tackle), inclined planes and wedges, screws, gears, lathe gearing, belts and pulleys, efficiency of machines, motion, cutting speeds, speeds of lathes, volume and pressure of gases, work and power, calculation of belting, energy, logarithms, measurement of right triangles, measurement of oblique triangles, electricity and strength of materials. As indicated in the foregoing enumeration of contents, the book covers a wide range of subjects, and of course it deals with the elements only.

Valves and Valve Gears. By Franklin DeR. Furman. 200 pages, 6 by 9 inches. 213 illustrations. Published by John Wiley & Sons, Inc., New York City. Price, $2, net.

The second part of this work on valves and valve gears treats of gasoline, gas and oil engines, while the first volume treated of steam engines and steam turbines. It deals with the general characteristics of internal combustion engines, the commercial applications of various forms of valves and valve gears to gasoline engines, gas engines, aeroplane engines, Diesel oil engines, and compares prime movers. This volume, doubtless, will be more highly appreciated, if possible, than the first, dealing as it does with the characteristics of the internal combustion motor which has become of such great importance within the last decade because of the widespread development of the automobile, the motor boat and the aeroplane. Valve constructions once believed to be out of the question for gas engines, are now freely admissible and some of them promise to rival the old reliable poppet valve because of their smoother action and more easily controlled operation. This treatise on valves and valve gears is recommended to all wishing to obtain an up-to-date and reliable work.

Principles and Practice of Linear Perspective. By Herman T. C. Kraus. 53 pages, 9½ by 14½ inches. Fifteen plates. Published by Norman W. Henley Publishing Co., New York City. Price, $2.50.

This is a well worked up and typographically pleasing work on the theory and practice of linear perspective as used in architectural, engineering and mechanical drawing. The book is made large enough so that complete perspective drawings in a fair scale can be reproduced on a single page. The plates are all at the left-hand side, while the descriptive text explaining the plate is given on the opposite page, making reference to the illustrations very convenient. The work comprises a complete course in perspective drawing. One of the plates entitled "Self-explanatory Linear Perspective Chart" gives in brief outline the fundamentals of perspective drawing, together with a clear illustration of the methods used. On this chart all construction lines are shown by fine dotted lines, and the names and purposes of these lines are clearly indicated. This chart alone constitutes, practically speaking, a condensed course in perspective drawing. The book can well be recommended to those who wish to make a comprehensive study of perspective drawing.

Problems Pertaining to Steel Tubes. By O. G. Wellton. 172 pages, 5 by 7 inches. 34 illustrations. Published by C. W. K. Gleerup, Lund, Sweden. Sold in the United States by D. Van Nostrand Co., New York City.

The author of this book, who for several years was lecturer and assistant professor of mechanical engineering in the School of Mining, Queens University, Kingston, Canada, has recorded in this book the results of his investigations into the mechanical problems pertaining to steel tubes when used as conductors of liquids above ground. The treatise is profound in character, dealing in a highly scientific manner with the subject, and analyzing it by the aid of mechanics and mathematics. As practically nothing has been published on this subject in the past, the book no doubt will prove of interest to those of an investigating type of mind, to whom mathematical discussions and scientific methods of treatment are not objectionable. The book is divided into a number of chapters, of which the first introduces the subject in a general manner, defines the problem, deduces the bending moments, derives the normal and shearing stresses, and discusses the maximum error due to approximations. The deformation of the shell is then taken up. In a second chapter, the problem is taken up, including the weight of the shell. This naturally complicates the whole question somewhat and, in a third chapter, the conclusions obtained in the two previous chapters are combined, thus treating as one the two problems previously proposed. The book gives evidence of great thoroughness in its preparation and is an example of the enormous amount of work required to investigate scientifically a single mechanical problem.

NEW CATALOGUES AND CIRCULARS

Gould & Eberhardt, Newark, N. J. Circular of a continuous circular milling machine.

Crucible Steel Co. of America, Pittsburg, Pa. Booklet of "Rex" high-speed steel, containing suggestions for heat-treatment, etc.

J. G. Blount Co., Everett, Mass. Catalogue 17 descriptive of the line of grinding and polishing machinery and speed lathes made by this company.

Royersford Foundry & Machine Co., 54 N. 5th St., Philadelphia, Pa. Circular of the "Excelsior" twenty-inch double back-geared vertical drilling machine.

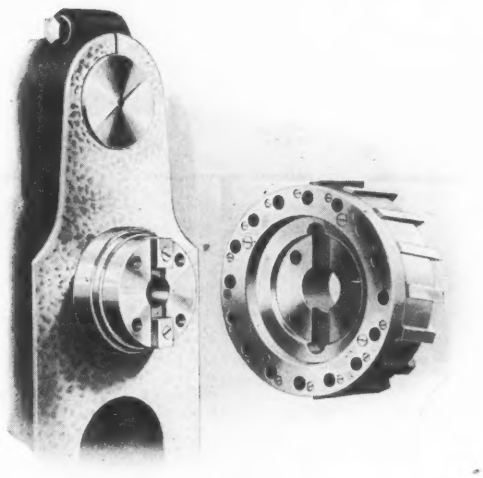
Hydraulic Press Mfg. Co., 84 Lincoln Ave., Mount Gilead, Ohio. Bulletin 5003 illustrating nosing and banding presses for use in the manufacture of steel shells.

American Blower Co., Detroit, Mich. Bulletin entitled "Sirocco Service," illustrating Sirocco heating and ventilating outfits installed in a large variety of plants.

Chicago Pneumatic Tool Co., Fisher Bldg., Chicago, Ill. Bulletin 130 on the lubrication of pneumatic tools, illustrating and describing automatic oilers and grease machines.

General Electric Co., Schenectady, N. Y. Pamphlets on constant-current transformers for "Mazda"

The Same Face Mill Can Now Be Used On 22 Different—



Flanged Spindle End and High Power Face Mill

CINCINNATI MILLERS

Because each of these machines has the same size spindle that we originally designed for the largest machine. A simple way of getting that very desirable thing—complete interchangeability of face mills—isn't it?

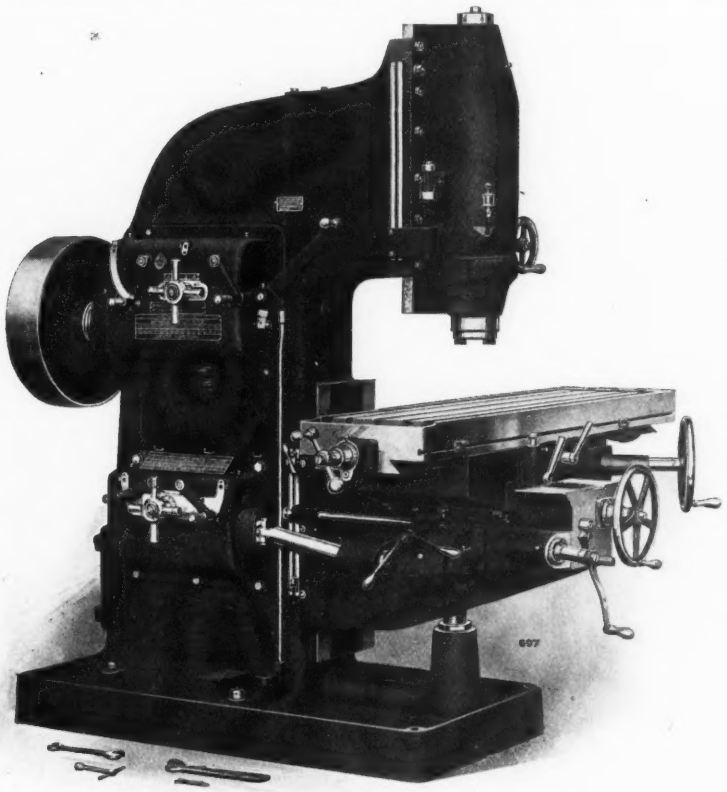
And that's where the improvement BEGINS. There's more to it.

Every man who's used a face mill knows the trouble he has had getting it off the spindle after a heavy drive. That was because of the threaded end.

Well, we've done away with that by abolishing the threaded spindle end.

The spindle ends are flanged and fitted with hardened keys.

Cutters are easily removed even after the hardest service.



The drive is entirely through the hardened keys which are fitted to and form part of the spindle.

Cutter Arbors for these machines have a similar flange with a corresponding keyway. They are driven direct by the same keys in the flanged spindle end that are used for driving face mills. There is no intermediate driving collar.

We have a Special Bulletin on this and other interesting improvements. Where shall we send your copy?

The Cincinnati Milling Machine Company

Cincinnati Ohio

street lighting systems, and "Novalux" street lighting units for "Mazda" series lamps.

Lumen Bearing Co., Buffalo, N. Y. Booklet on babbitt metals, listing the general line of babbitts made by this company, and giving the composition of each and the use for which they are adapted.

Speed Controller Co., Inc., 257-259 William St., New York City. Circular of the arc controller, a device for regulating the feed of the carbons in arc lamps so as to maintain perfect lighting efficiency continuously.

Columbus Lift Truck Co., Columbus, Ohio. Circular of the Columbia lift truck for handling materials. This truck is made in three styles and two capacities—the capacities being 1000 to 1500 pounds, and 2000 to 2500 pounds.

Lapointe Machine Tool Co., Hudson, Mass. Catalogue of Lapointe machines and tools for broaching. Some interesting examples of work done on this machine are shown, illustrating the economies that can be effected by broaching.

Hydraulic Press Mfg. Co., 84 Lincoln Ave., Mount Gilead, Ohio. Bulletin 5002 illustrating and describing a hydraulic press designed for billet piercing and drawing operations on steel shells. These presses have pressure capacities ranging from 150 to 1000 tons.

National Machinery Co., Tiffin, Ohio. Tapper Talk 11 discusses the retooling of the National automatic (bent tap) nut tapper. It is claimed that the average operator, after a little experience, can change the machine when tapping square nuts for tapping hexagon nuts, or vice versa, in fifteen or twenty minutes.

Baldwin Locomotive Works, Philadelphia, Pa. Record No. 81 on the triple articulated compound locomotive built for the Erie Railroad Co., illustrating and describing in detail this ponderous locomotive which has twenty-four driving wheels; the total weight is 853,050 pounds and the tractive effort 160,000 pounds when working compound.

New Departure Mfg. Co., Bristol, Conn. Bulletin 43 FE of miscellaneous nut locking and bearing retention methods of value in machinery design; 44 FE, ball bearings in portable electrically-operated drilling machine; 45 FE ball bearings for water and air pump crankshafts; and 46 FE, ball bearing mounting for lineshaft friction clutch.

Thomas Elevator Co., 20-22 S. Hoyne Ave., Chicago, Ill. Circular of the "Baker" wrenchless chucks for lathes. The Baker wrenchless chuck is operated by a hand lever, the opening and closing of the jaws being actuated by a set of gears constantly in mesh, two of which are mounted on swinging arms to which the lever is attached.

Westinghouse Electric & Mfg. Co., East Pittsburg, Pa., has recently issued leaflets 3805, 3806, and 3807 on the application of automatic control apparatus to cranes and steel mills. They show the scheme of main connection, and describe the method of operation of the magnetic unit switches, as arranged for the severe service of steel mill practice.

Boston Gear Works, Norfolk Downs, Mass. Catalogue E8 of cut steel, cast iron and brass spur gears, brass racks, brass internal gears, steel, cast-iron and brass bevel gears, worms and worm-wheels, helical gears, ratchets, sprockets, transmission chain, universal joints, hobs, automobile gears, Hindley worm-gears, etc. Data and tables useful to mechanics are included.

Union Chain & Mfg. Co., Seville, Ohio. Folder describing the construction of the new Union steel rivetless chain. The links of this chain are stamped and formed in one piece, producing a rigid and self-contained construction that dispenses with riveting. When worn, the bushings and pins can be used upside down, thus bringing the unworn surfaces into service and giving the chain a double life.

Joseph Dixon Crucible Co., Jersey City, N. J., has published a twenty-page treatise by F. J. Jarosch, chief engineer of the Bearings Co. of America, entitled "The Use and Abuse of Ball and Roller Bearings." The text gives help in the selection, mounting and lubrication of ball and roller bearings in automobile construction, etc. Nineteen drawings were used to illustrate the article.

Standard Machinery Co., Auburn, R. I. General catalogue on presses, illustrating reducing presses—plain and back-geared—inclinable presses, arch frame presses, toggle or knuckle joint embossing presses, transfer presses, cut and carry presses, heavy double-acting and cam presses, armature notching presses, etc. The clutches used on the "Standard" power presses are described and illustrated in detail.

A. D. Granger Co., 90 West St., New York City. Bulletin 2 describes and illustrates the latest improved features of the "Oswego" internally fired water-tube boilers, and gives tables of dimensions, ratings and other data for both high-pressure and low-pressure boilers. The booklet shows illustrations of buildings in which these boilers have been installed, among which are office buildings, public schools, apartment houses, factories, etc.

International Oxygen Co., Newark, N. J. Catalogue of the I. O. C. system production of pure oxygen and hydrogen for the use of plants desiring to produce their own gases for oxy-acetylene welding and cutting. The method utilized in this system consists in separating water into its constituents—oxygen and hydrogen—by means of an electric current. The advantages claimed for the system are low cost of operation, safety, durability, simplicity of operation, regularity, and the fact that no attention is required beyond the addition of the necessary amount of distilled water daily. The book illustrates a large number of installations of I. O. C. plants in the United States and abroad.

Wells Brothers Co. Division Greenfield Tap & Die Corporation, Greenfield, Mass. Catalogue 34 on the "Little Giant" line of screw cutting tools and machinery, which includes taps, dies, screw-plates, die-stocks, reamers, gages, automatic opening dies, threading machines, ratchet wrenches, etc. A folder in the front of the book lists the changes and additions that have been made since previous catalogue 30 was published. This catalogue is very comprehensive, containing 319 pages, 4½ by 7¼ inches. In addition to illustrating the general line, it includes many tables of useful information, among which are tables of tap drill sizes, giving the corresponding size of drills for every size and pitch of different thread standards.

American High-speed Chain Co., Commercial Drive Division, 608 S. Dearborn St., Chicago, Ill. Catalogue on American high-speed silent chain made in any pitch and width for all purposes. The catalogue shows this type of chain installed for various power transmission purposes, and gives suggestions on its erection, lubrication, etc. Some of the advantages claimed for this chain are that it is silent running, does not slip, is adaptable for use in cramped or other difficult positions, is unaffected by heat, cold, moisture or greases, maintains positive and correct gradation of speeds, and drives cutting tools smoothly. The book contains tables of horsepower of chains and dimensions of regular type, double-side bar type and single-side bar type chains.

National-Acme Mfg. Co., Cleveland, Ohio. New blueprinted catalogue of National-Acme auxiliary screw making machines. The special machines illustrated and described are adapted to the so-called auxiliary operations on small work that must be completed after the parts leave the screw machines. The machines shown comprise semi-automatic screw slotting machines, single-spindle drilling machine, semi-automatic multiple-spindle drilling machine, automatic six-spindle drilling machine, stud threading machine, two-spindle bolt threaders, screw head shaving machine, coupling tapper, tool grinder and self-opening die-head. The illustrations in the book are blueprints and the reading matter is printed in blue ink, presenting a unique and attractive appearance.

Ford Motor Co., Detroit, Mich., has issued a pamphlet entitled "Helpful Hints and Advice to Ford Employes" that outlines the Ford profit-sharing plan. The book is intended to supplement the work of the Ford investigators, but should prove of interest to others engaged in welfare work. The object of the Ford plan is to improve the living conditions and morals of Ford employes, and to encourage habits of thrift and saving. The illustrations show types of good and bad homes, sanitary and unsanitary living conditions and good and bad neighborhoods. Of particular interest are the views showing workmen's homes before and after the inauguration of the profit-sharing plan. The "Safety First" section gives suggestions for the prevention of accidents both in the shop and in the home, and shows some horrifying examples of the result of neglecting the necessary precautions.

TRADE NOTES

Frost Gear & Machine Co., Jackson, Mich., manufacturer of gears and forgings, has changed its name to the Frost Gear & Forge Co.

Chicago Automatic Machine Co., Chicago, Ill., maker of automatic screw machines, has erected a large addition to its factory which doubles its capacity.

Vitrified Wheel Co., Westfield, Mass., manufacturer of grinding wheels, has begun the construction of a two-story addition, 40 by 100 feet, to its main factory.

Mechanical Handlor Co., Hudson, N. Y., builder of elevating and conveying machinery, has erected a new factory, and equipped it with machine tools suited to jobbing and general manufacturing.

American Steel Foundries, McCormick Bldg., Chicago, Ill., has installed a six-ton electric furnace of the Heroult design at its Indiana Harbor, Ind., plant, for the manufacture of extra quality steel castings.

Monarch Machine Co., Sidney, Ohio, manufacturer of the "Monarch" engine lathe, has just completed another addition to its plant. The new building is 56 by 200 feet. The firm name has been changed to Monarch Machine Tool Co.

Tropenas Converter Co., 50 Church St., New York City, has opened a new laboratory at 2243 Nostrand Ave., Brooklyn, N. Y., where business of an executive nature will be transacted. The office at 50 Church St. will be maintained also.

Enkel Motor Co., Inc., Auburn, N. Y., has developed a four-cylinder Diesel type motor which operates successfully on kerosene oil. The expectation is that the new engine will be used for motor cars, kerosene being the fuel instead of gasoline.

L. H. Gilmer Co., 52 N. Seventh St., Philadelphia, Pa., manufacturer of endless belts, announces that Manning J. Smith, formerly treasurer, has been succeeded by J. S. Krauss, secretary, who was elected to the office of treasurer, thereby becoming secretary and treasurer.

Burke Electric Co., Erie, Pa., manufacturer of electric motors and generators, electric arc welding equipments, motor-generator sets, transformers, etc., has appointed W. T. Osborn as its direct sales representative in charge of the Kansas City branch sales office located at 1505 Commerce Bldg.

Hydraulic Press Mfg. Co., 84 Lincoln Ave., Mount Gilead, Ohio, announces that the following officers have been elected: A. Q. Tucker, president; W. G. Beebe, vice-president; Frank B. McMillin, general manager and secretary; and M. W. Spear, treasurer. Dr. N. Tucker has been added to the directorate.

Aurora Steel Co., Aurora, Ill., has been incorporated by Alex. Nelson, D. R. Furnas, A. R. Carlson and P. R. Sparks. The incorporators were formerly with the All Steel Equipment Co. of Aurora. The new concern will manufacture machine shop equipment such as racks, bins, tote pans, etc., and a general line of factory equipment.

Hydraulic Press Mfg. Co., 84 Lincoln Ave., Mount Gilead, Ohio, made an exhibit of hydraulic presses and machinery at the Panama-Pacific International Exposition. The grand prize from the department of agriculture for press machines and the gold medal from the department of machinery, for forcing and bending presses and equipment, were awarded.

Waltham Emery Wheel Co., Waltham, Mass., manufacturer of grinding wheels has changed its corporate name to the Waltham Grinding Wheel Co. The change was made to eliminate the term "emery" which was a misnomer, giving the impression that the company's product consisted of emery wheels, when as a matter of fact its wheels are made principally of electric furnace abrasives.

Pedrick Tool & Machine Co., 3639 Lawrence St., Philadelphia, Pa., recently purchased the business, machinery, stock and equipment of the Sterling Machine Co., Norwich, Conn., manufacturer of the "Marathon" tool grinders and the "Sterling" grinder. It is the intention of the purchaser to continue the manufacture and sale of these grinders, following the reorganization of the business under its own management.

American Express Co., 65 Broadway, New York City, has opened an office in Buenos Aires in charge of A. B. Howard, manager of the company's South American department. Manufacturers are invited to investigate the service that will be rendered, which includes negotiating foreign exchange, forwarding freight and packages, examining opportunities for trade, displaying catalogues, making collections, looking after the mail of patrons, etc.

Westinghouse Electric Export Co., 165 Broadway, New York City, announces the election of the following officers at the meeting of the board of directors held July 28: E. M. Herr, president; L. A. Osborne and Calvert Townley, vice-presidents; Maurice Coster, managing director; J. C. Bennet, secretary; and H. D. Shute, treasurer. President E. M. Herr appointed E. D. Mills manager, E. R. Ellis, European manager and H. F. Griffith, assistant export manager.

Cowan Truck Co., Holyoke, Mass., maker of the Cowan transveyor, had the distinction of having its transveyor selected at the Panama-Pacific Exposition for transporting the Liberty bell to its place. The transveyor used is of a heavy hydraulic type, built to elevate and carry five thousand pound loads. The bell which weighs 2080 pounds has up to this time been a cumbersome object to handle, a large derrick having been the means heretofore of moving it from one place to another.

American Emery Wheel Works, Waterman, East River and Pitman Sts., Providence, R. I., is completing large additions, including a new third-floor office 50 by 100 feet. The remainder of the third floor, approximately 50 by 200 feet, together with the first floor space vacated as offices, has been released for additional factory purposes. A new kiln building and four additional fifteen-foot kilns are being erected. All necessary equipment including new elastic oven, gravity elevator system, etc., has been purchased.

Sociedad General de Representaciones, Madrid, Spain, contractors to Spanish war and navy offices, public works, railroad and tramway companies and dealers in American machine tools, elevators, cranes, derricks, electric machinery, locomotives, automobiles, motor trucks, ammunition, etc., have established a New York City office in Room 603, 30 Church St. The office will be under the personal direction of the company's general manager, Henry S. Moos and he will be assisted by Dwight W. Grover, manager of the New York office.

National Tube Co., Frick Bldg., Pittsburg, Pa., was awarded the grand prize, the highest possible regular award for the general excellence of its tubular products and fittings exhibited at the Panama-Pacific International Exposition. The greatest merit was recognized in the following special products: "National" oil well casing, tubing, drill pipe, drive pipe, drill pipe and tubing with upset ends, line pipe, lead joint pipe, "Spellerized" pipe and boiler tubes, and steel poles; "National" protective coating; "Kewanee" unions, valves and fittings; Shelby special alloy steel tubing, cylinders, flasks, steam pipe, drill pipe, mechanical tubing and trolley poles.

Fore River Shipbuilding Corporation, Quincy, Mass., is building a plate and angle shop, 188 feet wide and 769 feet long. The building has steel columns and trusses with a plank roof covered with tar and gravel. The sides are largely of glass in steel sash, with pilasters of brick. There is one high story for handling plates and angles for shipyard work. A partial second story above this includes the mold loft, 92 feet wide by 605 feet long and a sheet metal shop 92 feet wide by 164 feet long. The Aberthaw Construction Co. of Boston, in charge of the building, is erecting the steel columns of unusually large rolled sections, some of them being 30-inch I-beams weighing 200 pounds per foot.

Turbo-Gear Co., Industrial Bldg., Baltimore, Md., maker of a helical reduction gear designed by G. Fast and described in the June, 1915, number, has made public reports of a test of a turbo-speed transformer conducted by the Consolidated Gas, Electric Light & Power Co. of Baltimore. The gear tested was designed for transmitting 25 H.P.